Repco AUTO TECH

2018.2

AUTO-TECH MASTERCLASS

Training for Master Technicians

Brake Booster Diagnosis

Brake Fluid Pressure Testing

Brake Fluid

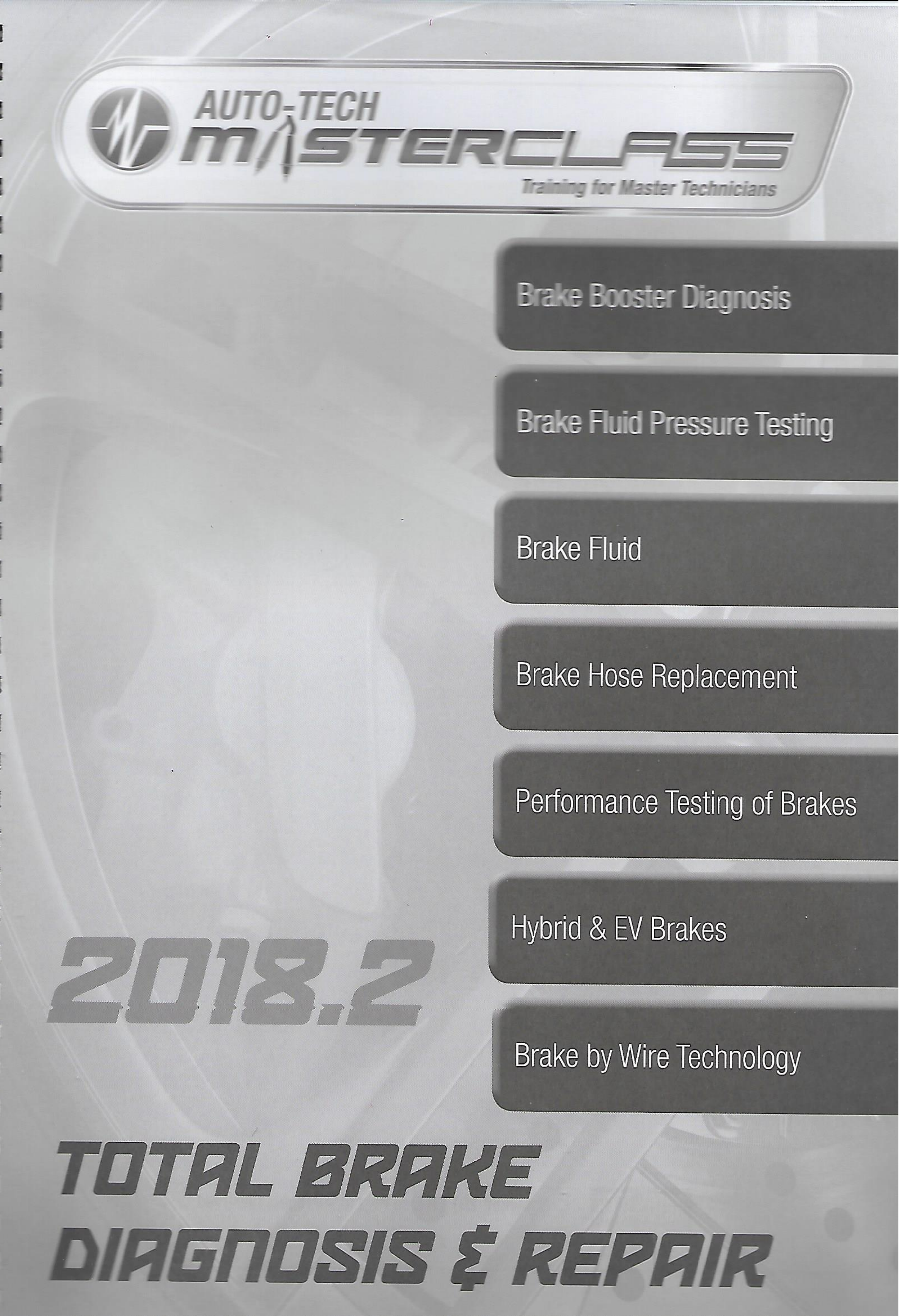
Brake Hose Replacement

Performance Testing of Brakes

Hybrid and EV Brakes

Brake by Wire Technology

TOTAL BRAKE DIAGNOSIS & REPAIR



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TOTAL BRAKE DIAGNOSIS & REPAIR

Section i

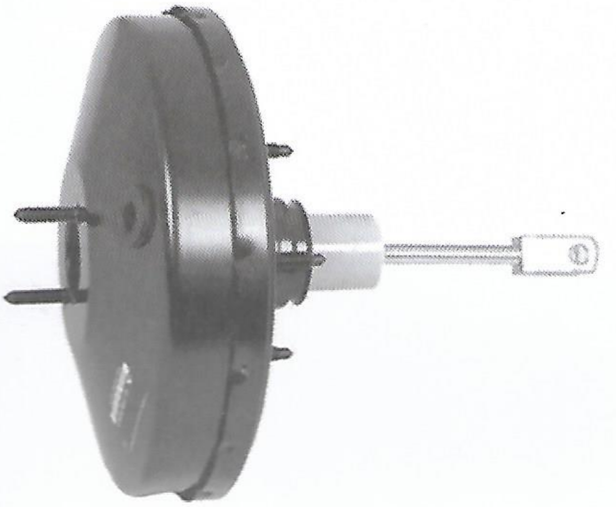
Brake Booster Diagnosis

CONTENTS

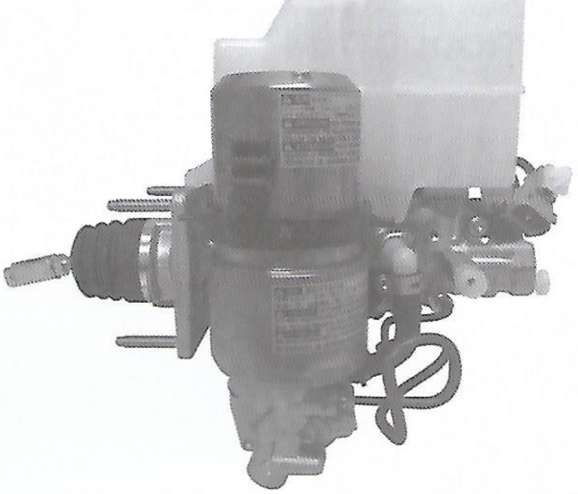
INTRODUCTION 4

INTRODUCTION

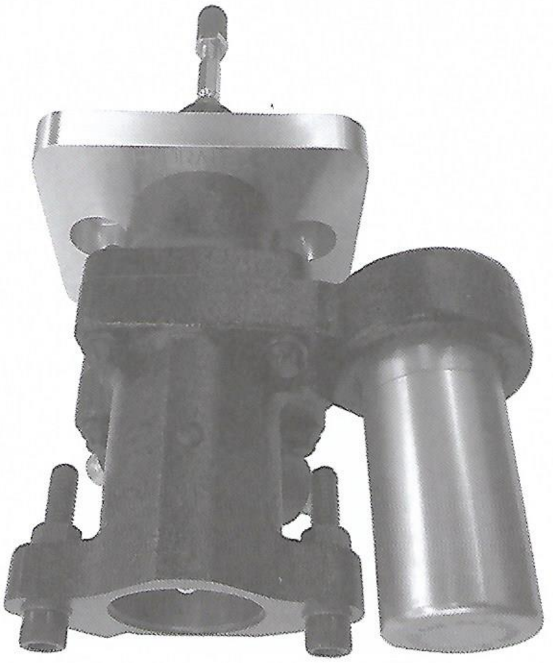
A Brake Booster provides assistance by reducing the Brake Pedal Force required to brake a vehicle. By and large the vast majority of vehicles employ a Vacuum (Servo) Brake Booster, although the Hydraulic Brake Booster (HBB) is gaining in popularity. The HBB should not be confused with the Hydra-Boost Unit, which was fitted to some vehicles in the US and available in Australia and New Zealand through performance part retailers as a modification accessory. The Hydra-Boost uses fluid pressure from the power steering system to provide braking assistance, whereas the HBB uses pressurised brake fluid for braking assistance.



Vacuum Brake Booster



Hydraulic Brake Booster



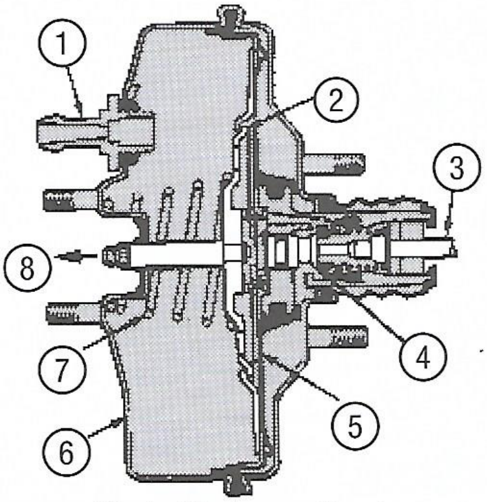
Hydra-Boost Type Booster Unit

Note: *Hydra-Boost Type Boosters were not fitted to any vehicles sold new in Australia or New Zealand!*

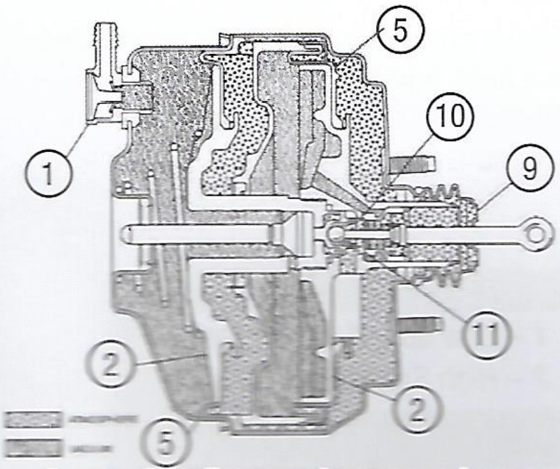
VACUUM BRAKE BOOSTERS

A Vacuum Brake Booster uses the vacuum supply (either from the intake manifold or a vacuum pump) to act upon one side of a diaphragm and provide assistance, most commonly to the pedal force applied to the Master Cylinder. The exception is the Remote Booster which amplifies the fluid pressure after the Master Cylinder.

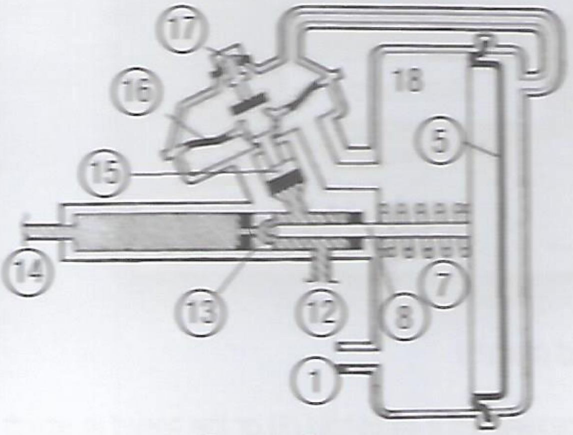
The Vacuum Booster is widely adopted and has three variations:



Single Diaphragm Booster



Double (Dual/Tandem) Diaphragm Booster



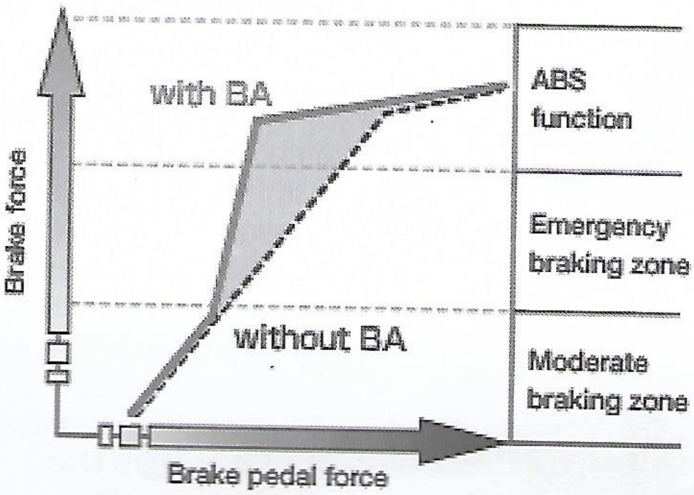
Remote Booster

The Single Diaphragm Booster is the most common. The Double Diaphragm Booster (also call dual or tandem) uses two vacuum chambers to amplify the surface area, this allows for smaller diameter at the expense of a greater overall length. While the remote booster is most commonly used on older vehicles where boosted brakes were not standard fitment.

1. Vacuum Port and Check Valve
2. Diaphragm Disc
3. Operating Rod
4. Atmospheric / Vacuum Port
5. Diaphragm
6. Cover
7. Return Spring
8. Push Rod
9. Atmospheric Filter
10. Vacuum Port
11. Atmospheric Port
12. Fluid Inlet (from Master Cylinder)
13. Slave Cylinder Piston
14. Fluid Outlet (to Brakes)
15. Air-valve Piston
16. Air-valve Diaphragm
17. Air Valve
18. Vacuum Chamber

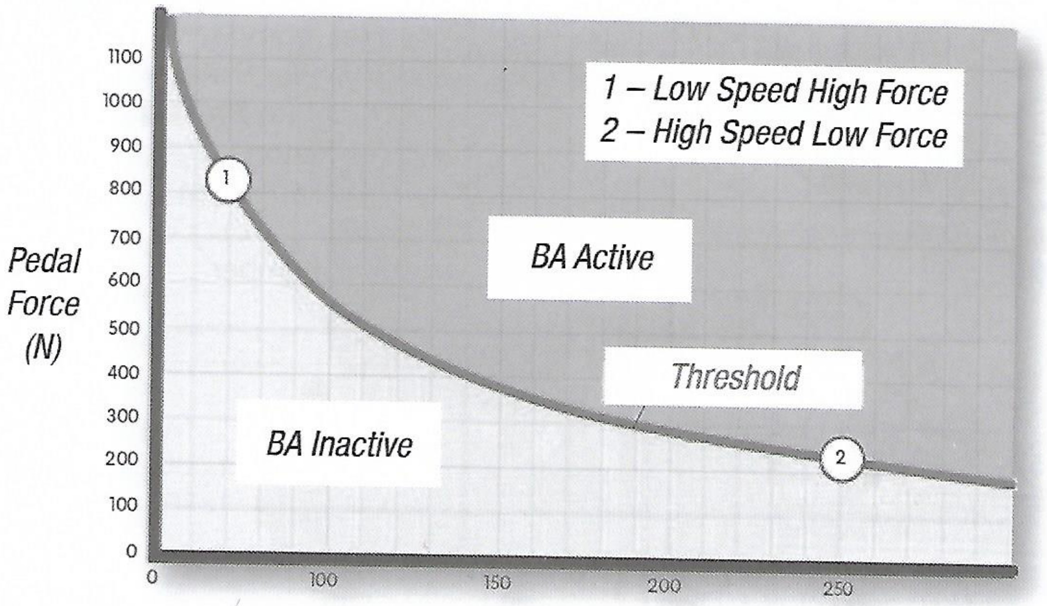
VACUUM BRAKE BOOSTERS continued...

Brake Assist
In 1992 Mercedes Benz found that in a simulator, 95% of drivers didn't apply enough brake force during an emergency stop. In a response to this simulator study they commissioned TRW to develop the first Brake Assist (BA) system. Tests have shown that stopping distances are 45% shorter for vehicles fitted with BA.



Benefits of Brake Assist (BA) - the shaded grey area represents the braking advantage gained

The first production vehicle to be fitted with a BA system was the 1996 Mercedes Benz S & SL Class models, with the entire Benz fleet having BA as standard by 1998. Other European manufacturers quickly followed and eventually the technology went global.



Brake assist will be activated whenever the brake force reaches a threshold (1) or the speed in which the pedal is depressed exceeds a threshold (2) and any combination of both.

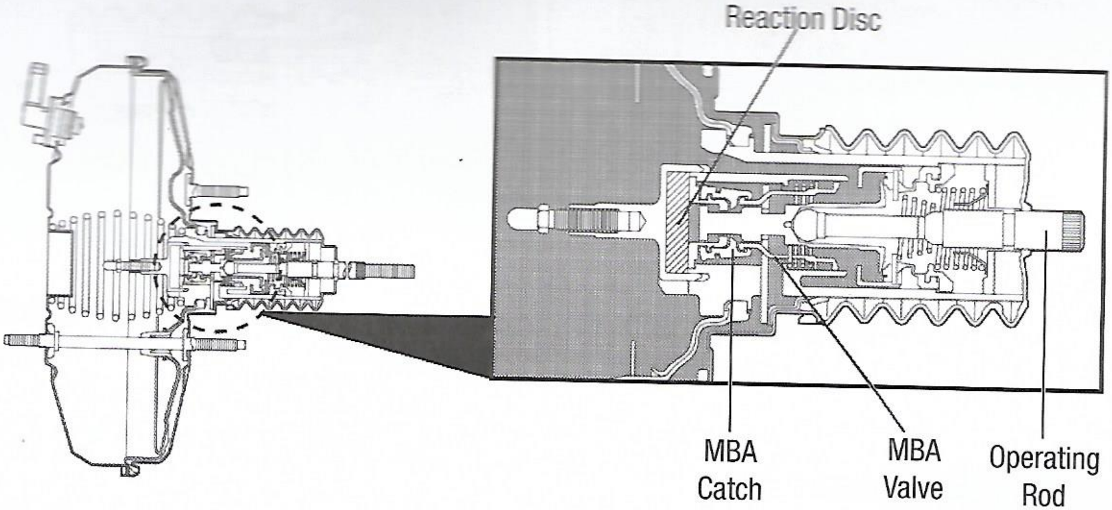
VACUUM BRAKE BOOSTERS continued...

There are three Brake Assist types used on vehicles with Vacuum Brake Boosters:

- Mechanical Brake Assist (MBA)
- Electronic Brake Assist (EBA)
- Hydraulic Brake Assist (HBA)

Mechanical Brake Assist (MBA)

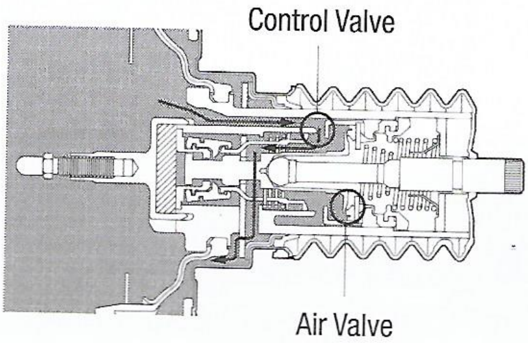
During the late 1990's through to 2013, many vehicles were fitted with a Vacuum Brake Booster (without Stability Control) and optioned with MBA. These vehicles utilise a mechanically activated load sensing two stage booster.



The Mechanical Brake Assist (MBA) system used by Toyota

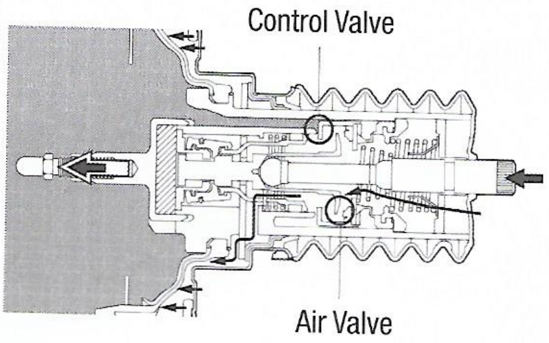
VACUUM BRAKE BOOSTERS continued...

Rest


Control Valve
Air Valve

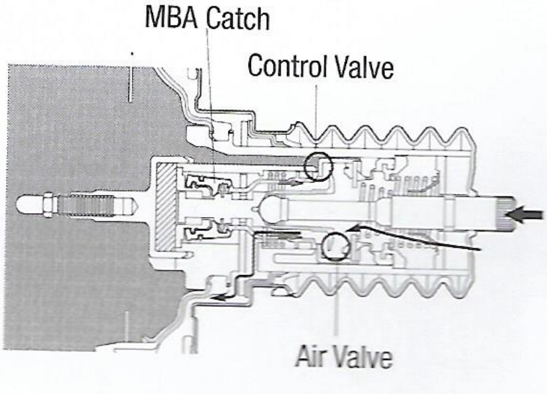
Control Valve OPEN, Air Valve CLOSED
Vacuum transfers to Variable Chamber

Normal Braking Event


Control Valve
Air Valve

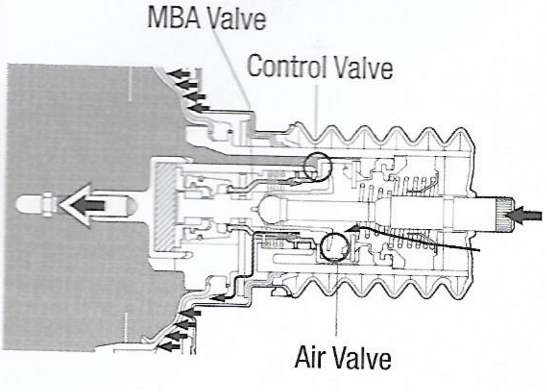
Control Valve CLOSED, Air Valve PARTIALLY OPEN
Vacuum depletes from Variable Chamber

Brake Assist Pt.1


MBA Catch
Control Valve
Air Valve

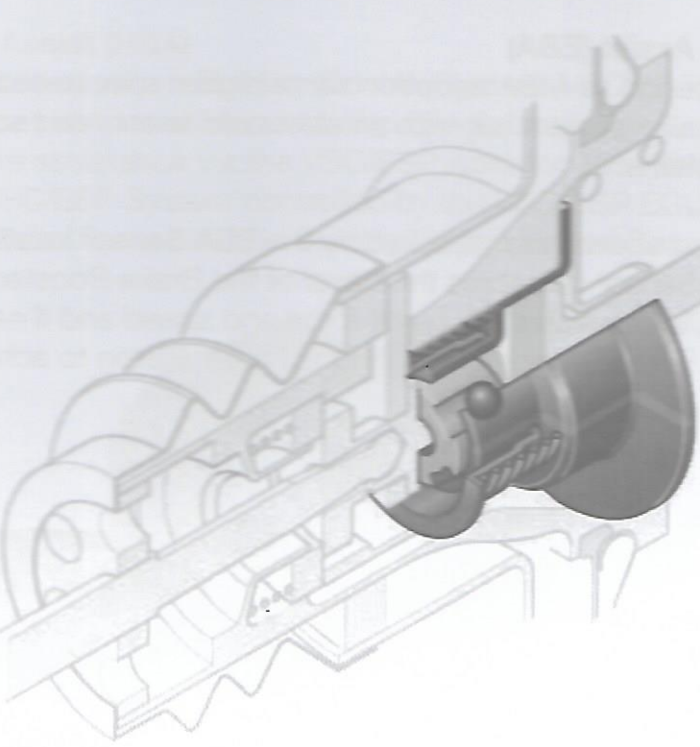
Operating Rod Speed/Force exceeds Power Piston Speed/Force, compressing Reaction Disc and releasing the MBA Catch

Brake Assist Pt.2


MBA Valve
Control Valve
Air Valve

Control Valve CLOSED, Air Valve FULLY OPEN
Vacuum dumped from Variable Chamber, maximum brake force applied

VACUUM BRAKE BOOSTERS continued...



The Volkswagen Group (VAG) MBA system replaces the MBA Catch with a Ball-and-Ramp type inertia mechanism but otherwise operates using the same principles

Popular vehicles that do have MBA (models with ABS and without ESP):

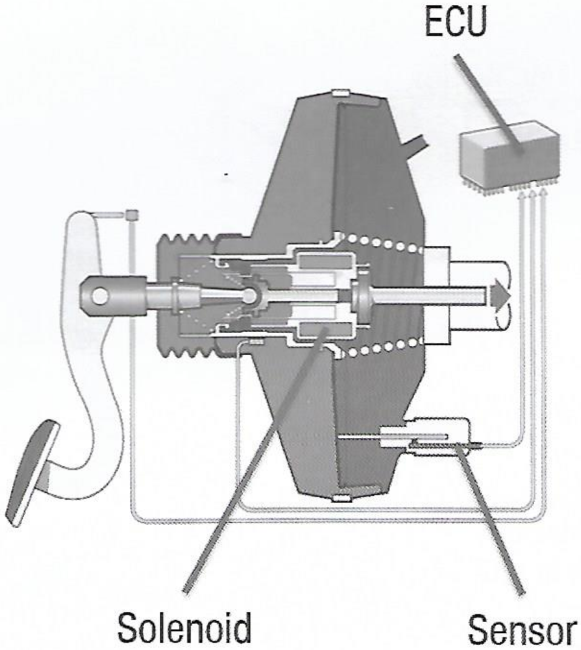
- Holden VZ Commodore
- Ford Mondeo Mk III (2000-07) – New Zealand ONLY
- Toyota 105 series LandCruiser
- Toyota 120 series Prado
- Nissan D40 Navara
- Nissan R51 Pathfinder

Many of the European models that were offered with MBA systems didn't make it to Australia and New Zealand, this was due to the delay in models being released here and in many circumstances these models were upgraded with Stability Control Systems (VSC/ESP) with Hydraulic Brake Assist (HBA). However it is extremely hard to prove that a vehicle has MBA. Larger Euro vehicles built after 1996 (Mercedes Benz) and 1998 (others) are all possible candidates.

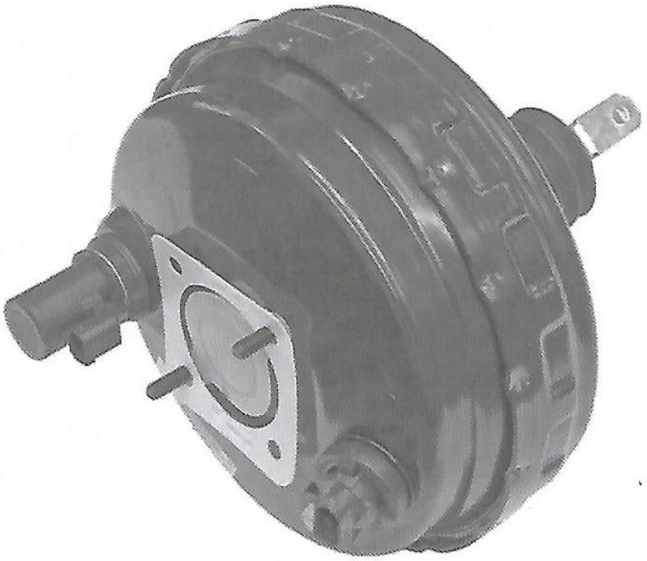
VACUUM BRAKE BOOSTERS continued...

Electronic Brake Assist (EBA)
During the same period as MBA adoption some higher-spec (mostly European) vehicles have a similar system but with an electronic sensor and solenoid actuator, these are EBA systems.

The pedal force and speed are measured by the EBA Sensor located on the booster. The EBA Sensor measures the travel of the Brake Booster Diaphragm Plate. The EBA ECU calculates the pedal force and speed and if needed energises the EBA Solenoid. The EBA solenoid pulls the Power Piston to achieve maximum braking force.



Typical Electronic Brake Assist (EBA) system

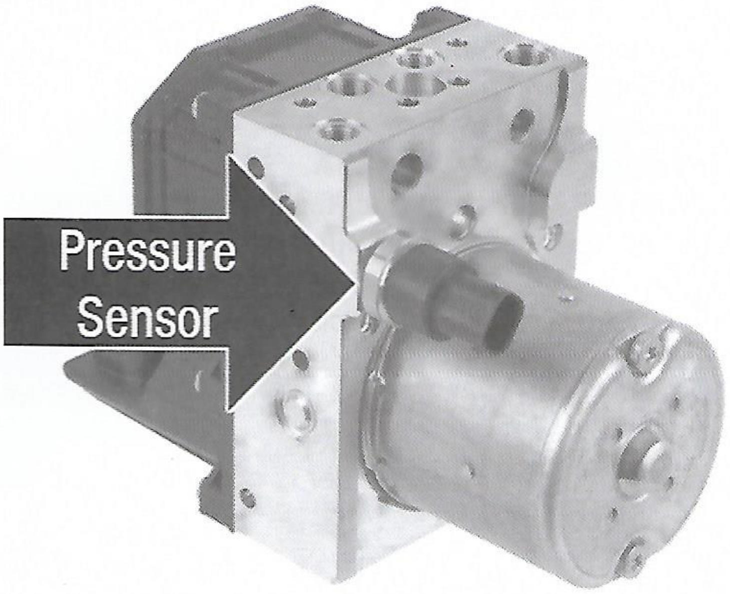


The Sensor on the Booster makes EBA systems easy to identify, this particular booster from a Mercedes W140 has a EBA Sensor (left) and a Vacuum Sensor (right)

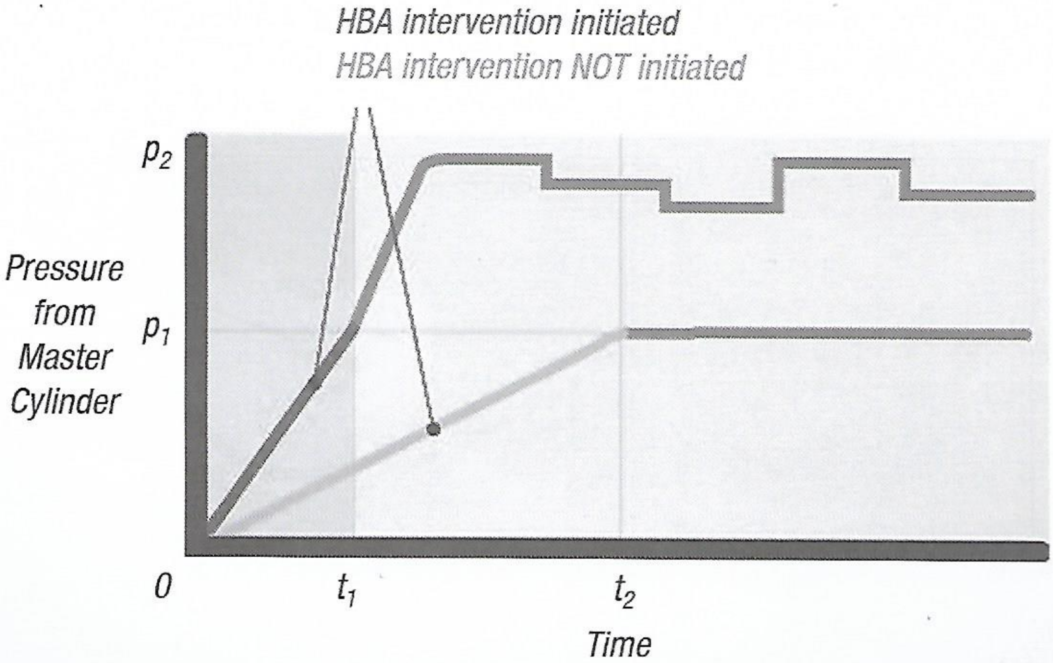
VACUUM BRAKE BOOSTERS continued...

Hydraulic Brake Assist (HBA)

Any vehicle that is fitted with a Stability Control System (VSC/ESP) will have an HBA system. These vehicles utilise a standard single stage vacuum booster and provide extra brake assistance via the VSC/ESP actuator. HBA becomes one of the functions of the VSC/ESP System controlled by the VSC/ESP ECU. The ECU uses signals from the Brake Pedal Position Switch, Vehicle Speed Sensors and Brake Pressure Sensor.



For vehicles fitted with a Vacuum Brake Booster and ESP/VSC the Brake Assist system is integrated into the ABS Modulator and the Pressure Sensor is a key component.



The ECU compares fluid pressure against time to determine if Brake Assist intervention is necessary. The fluctuating pressures across the top of the graph represents the ABS intervention.

VACUUM BRAKE BOOSTERS continued...

Basic Brake Booster Test

1. Booster must have at least 61kPa (18"Hg) at idle, in gear (auto trans)
    - 68kPa (20"Hg) preferred
2. Must hold full vacuum for at least 5 minutes
3. Must provide at least one application after vacuum supply is removed
    - The number of applications varies on pedal force used
    - Generally between 2 and 3
    - Generally 17-34kPa (5-10"Hg) depleted for each application
4. With full vacuum supply depress and hold the brake pedal for 30 second, vacuum should deplete no more than 34kPa (10"Hg) and then hold steady.

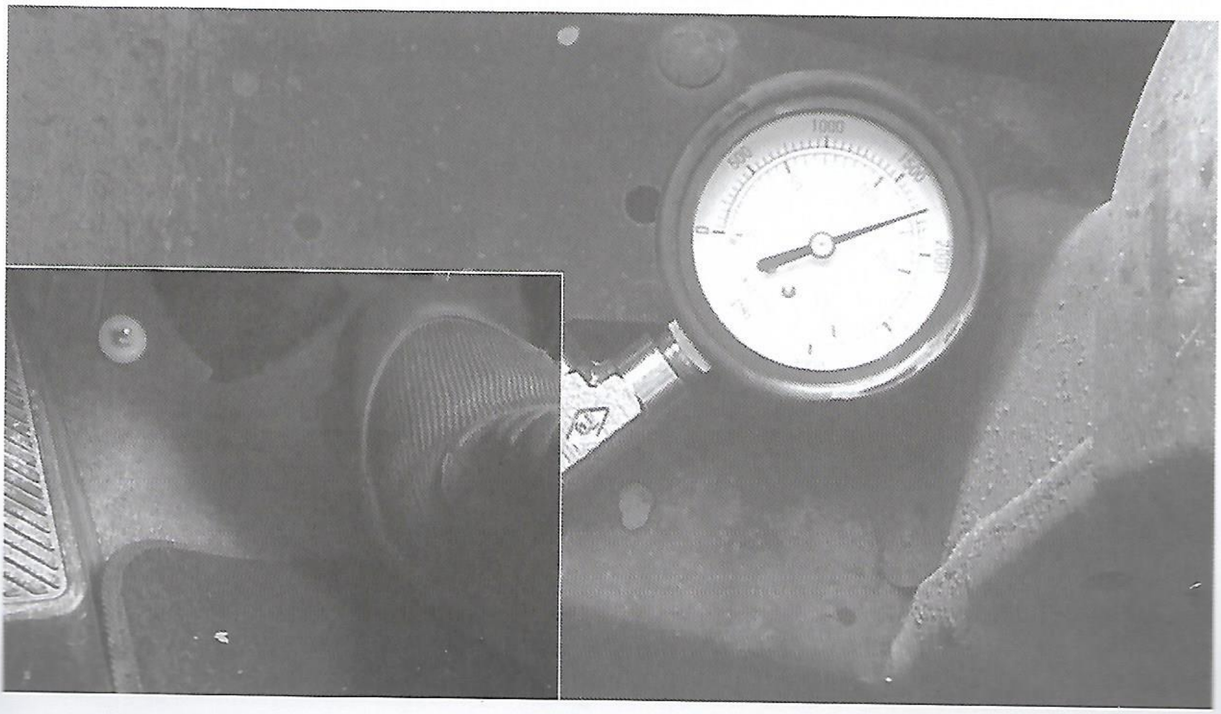
Poor pedal feel for vehicles fitted with MBA

Most vehicles fitted with MBA will have a softer brake pedal, many technicians will consider the brake pedal 'feel' to be poor. But this is normal!

These vehicles are quite difficult for a technician to out-rightly state that brake pedal is good/bad/normal. On many of these vehicles it is possible to push the pedal to the floor when prolonged heavy force is applied.

If a poor pedal feel is suspected or a customer is complaining about pedal feel, carry out the following procedure:

1. Check brake fluid condition and replace if required
2. Check the pedal with the booster depleted of vacuum
   (the pedal should not sink to the floor without booster assistance)
3. Carry out a brake pressure test
   (even though the pedal sinks towards the floor the fluid pressure should not drop at any stage)



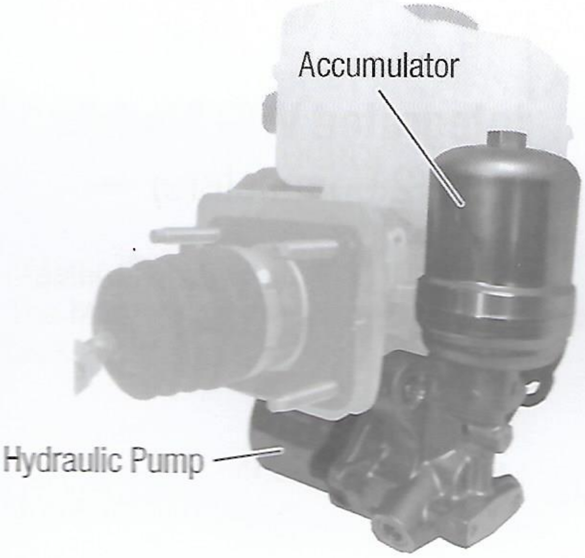
HYDRAULIC BRAKE BOOSTERS continued...

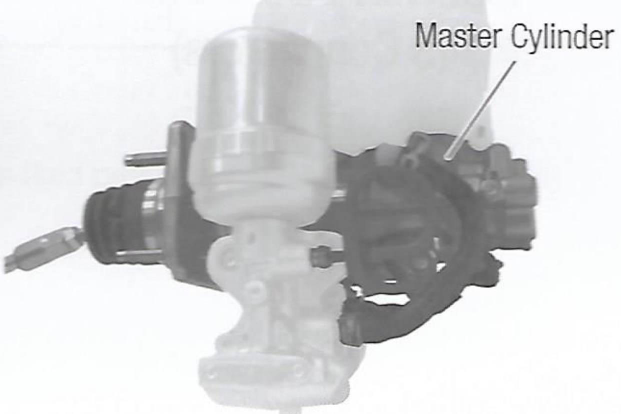
Introduction

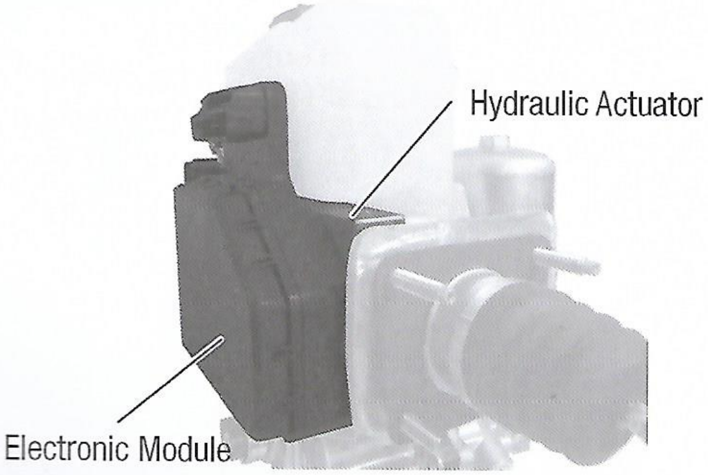
The first vehicle to be fitted with a Hydraulic Brake Booster (HBB) was the 1997 Lexus GS300 (JZS160R). In 2000 Toyota introduced the HBB into the LandCruiser Diesel (HDJ100R) and the LandCruiser Prado Diesel (KZJ95R). The reason for first entering diesel models was that it avoided the need for a vacuum pump. Other models to be fitted with the Advics HBB were the 2001 Prius (NHW11R) and in 2003 it was modified into a full brake-by-wire system for the new Prius (NHW20R). Mitsubishi employed the Advics HBB in the 2007 Pajero and the Nissan Patrol (Y62) from 2013.

The Hydraulic Brake Booster integrates the following components and systems:

- Master Cylinder
- Anti-Lock Braking System (ABS) Actuator
- Reservoir
- High Pressure Hydraulic Pump
- Accumulator
- Vehicle Stability Control Module (VSC) - 2004MY onwards
- Brake Assist - 2004MY onwards

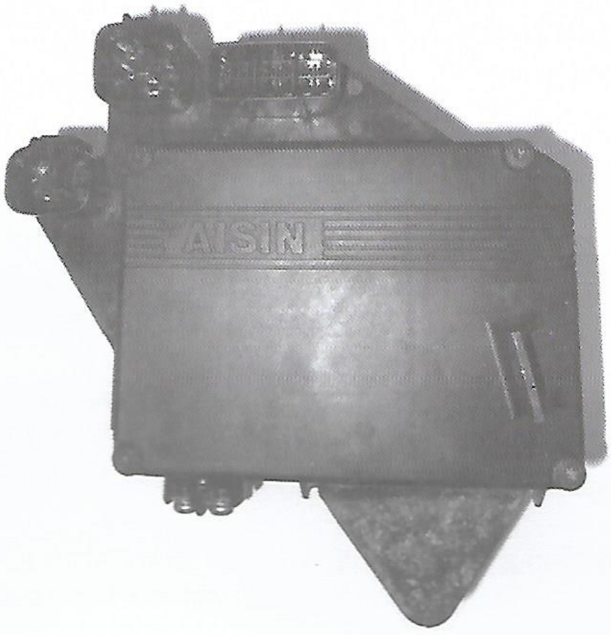




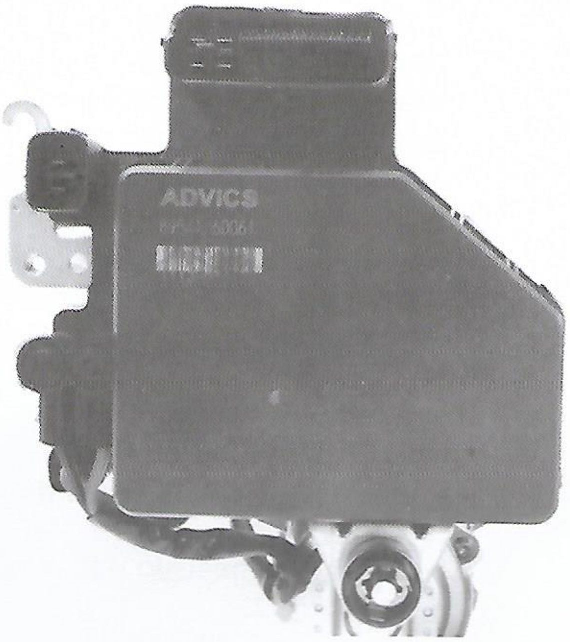


HYDRAULIC BRAKE BOOSTERS continued...

The system has remained largely unchanged since its introduction, with only one significant modification, which was the integration of the VSC/ESP Module for the 2004MY. Pre-2004 vehicles had a remotely located VSC Module. These can be identified by the three connectors on the Hydraulic Brake Booster.



External VSC Module
(3 Connectors)



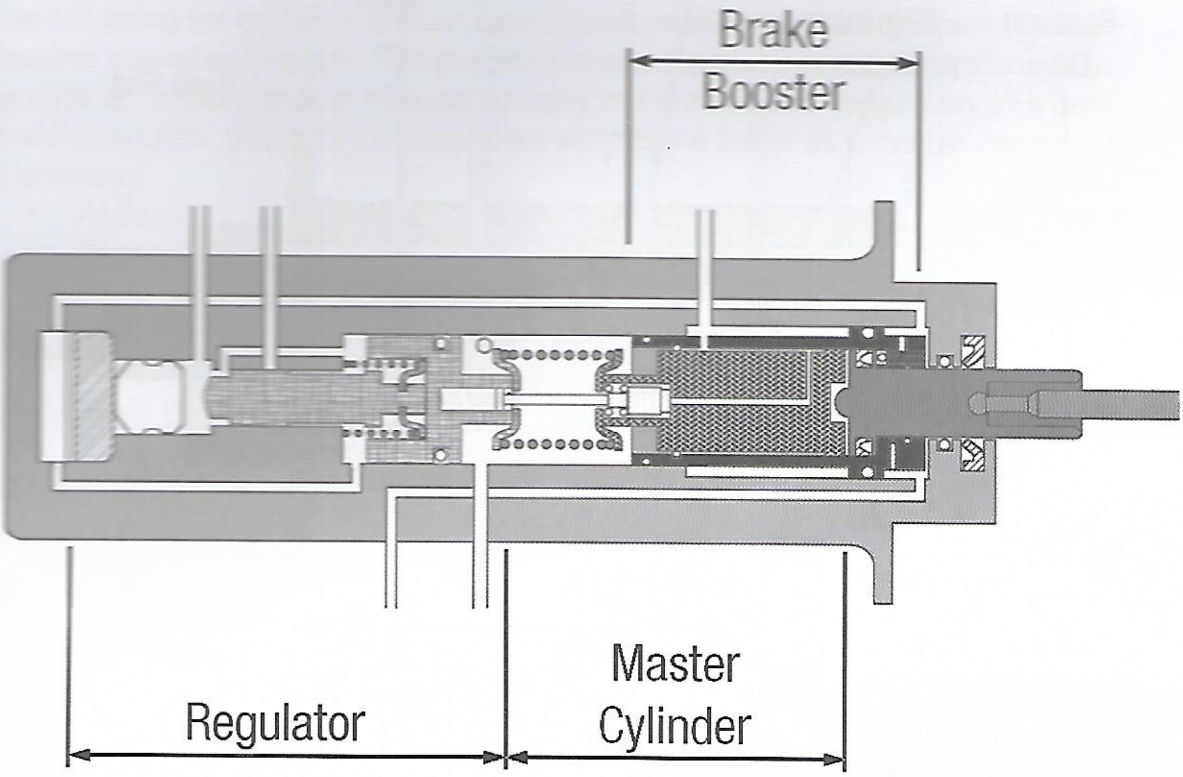
Integrated VSC Module
(2 Connectors)

HYDRAULIC BRAKE BOOSTERS continued...

Master Cylinder Assembly

The Master Cylinder Assembly is made up of 3 hydraulic circuits:

1. Master Cylinder
2. Regulator
3. Brake Booster



Master Cylinder

The Master Cylinder creates the hydraulic fluid pressure needed to apply the brakes.

Regulator

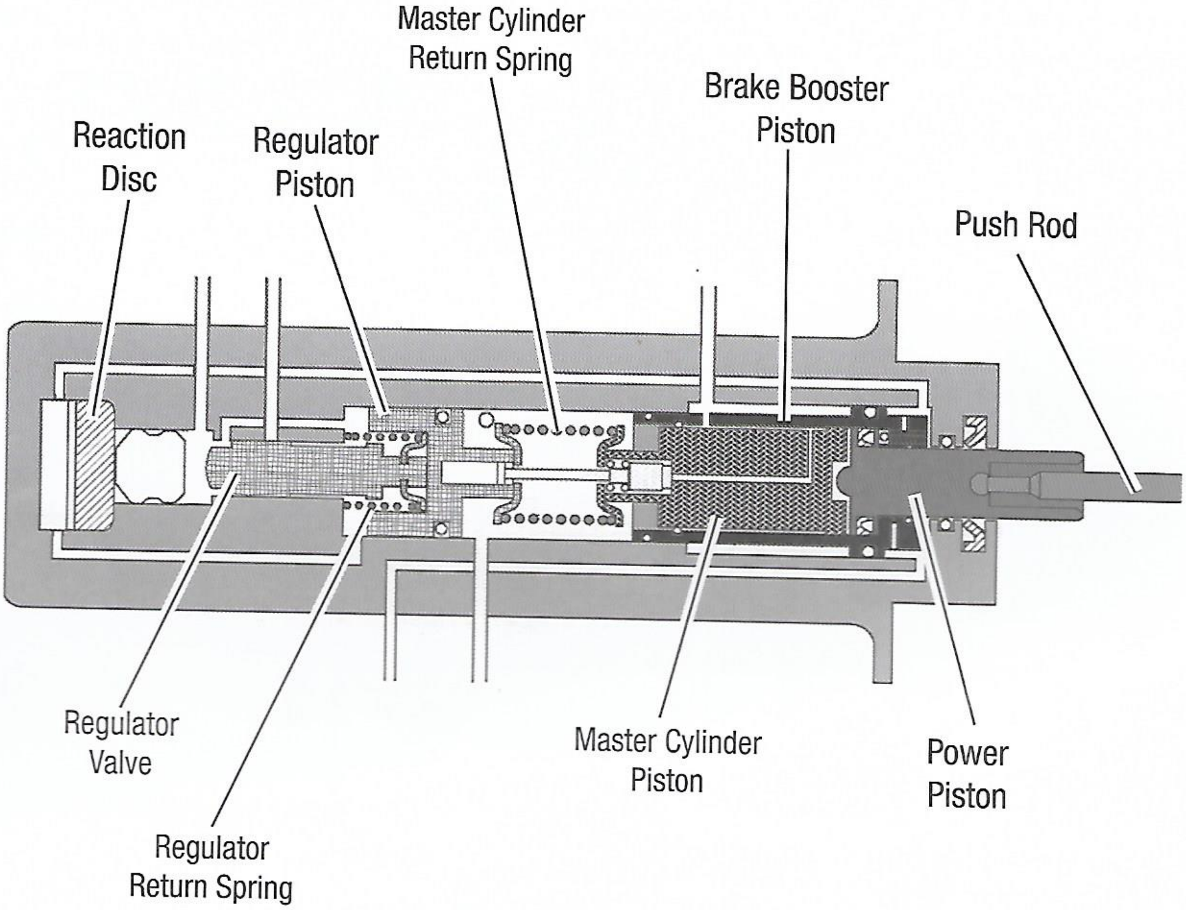
The Regulator controls the amount of pressurised fluid that is applied to the Brake Booster Piston for assistance.

Brake Booster

The Brake Booster is controlled by the regulator and reduces pedal effort by helping the application of the Master Cylinder Piston.

HYDRAULIC BRAKE BOOSTERS continued...

Components


Master Cylinder
Return Spring
Brake Booster
Piston
Reaction
Disc
Regulator
Piston
Push Rod
Regulator
Valve
Master Cylinder
Piston
Power
Piston
Regulator
Return Spring

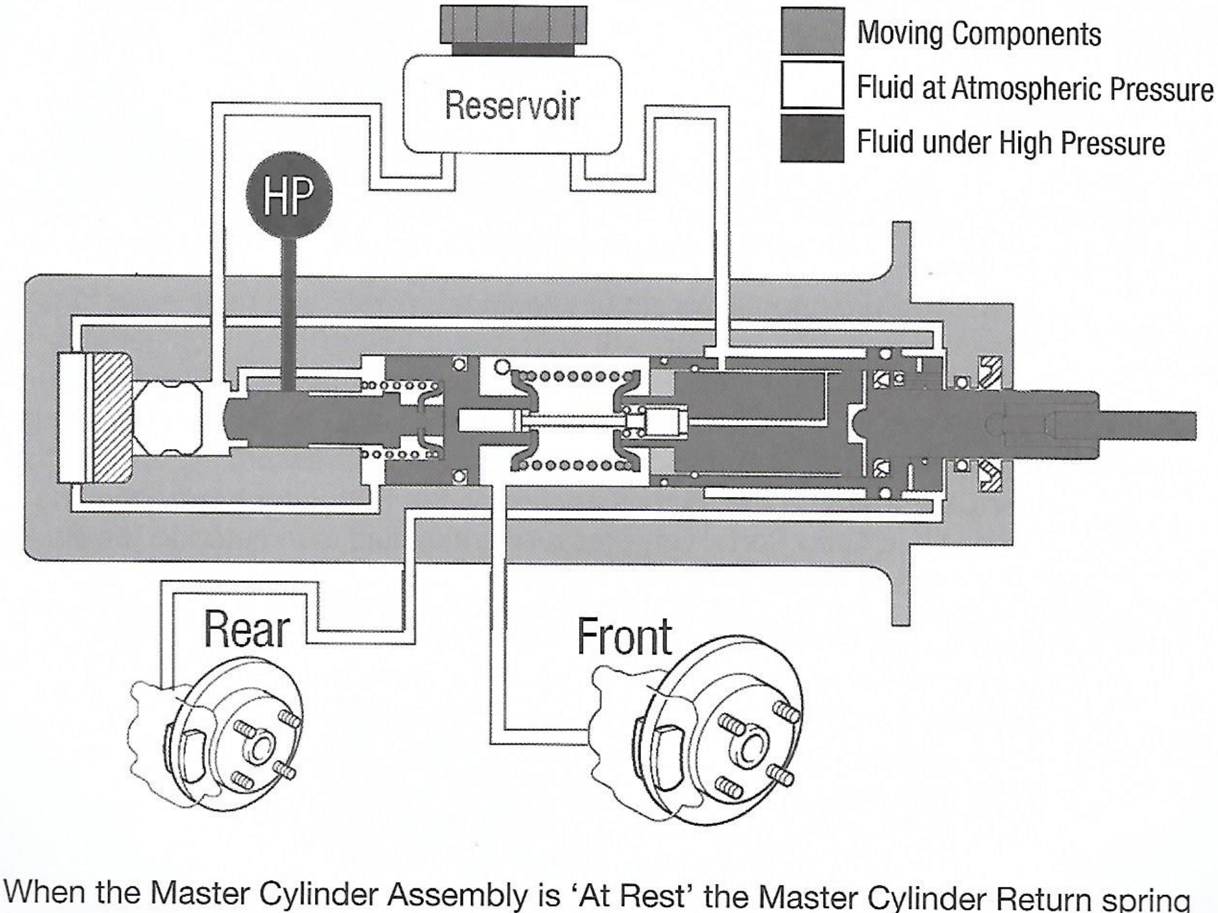
HYDRAULIC BRAKE BOOSTERS continued...

Operation
To understand the bleeding process you must first understand the basic operation of the Hydraulic Braking system and how it differs from a typical vacuum boosted system.

The following list covers the main operational modes that the Hydraulic Brake Booster operates through. The purpose of the diagrams and descriptions is to provide an understanding needed to carry out service and repairs on a Hydraulic Braking system and is by no means an exhaustive list of all possible operational scenarios:

- At Rest
- Braking (stage 1)
- Braking (stage 2)
- Heavy Braking
- High Pressure Supply or Rear Brake Circuit Malfunction
- Front Brake Circuit Malfunction

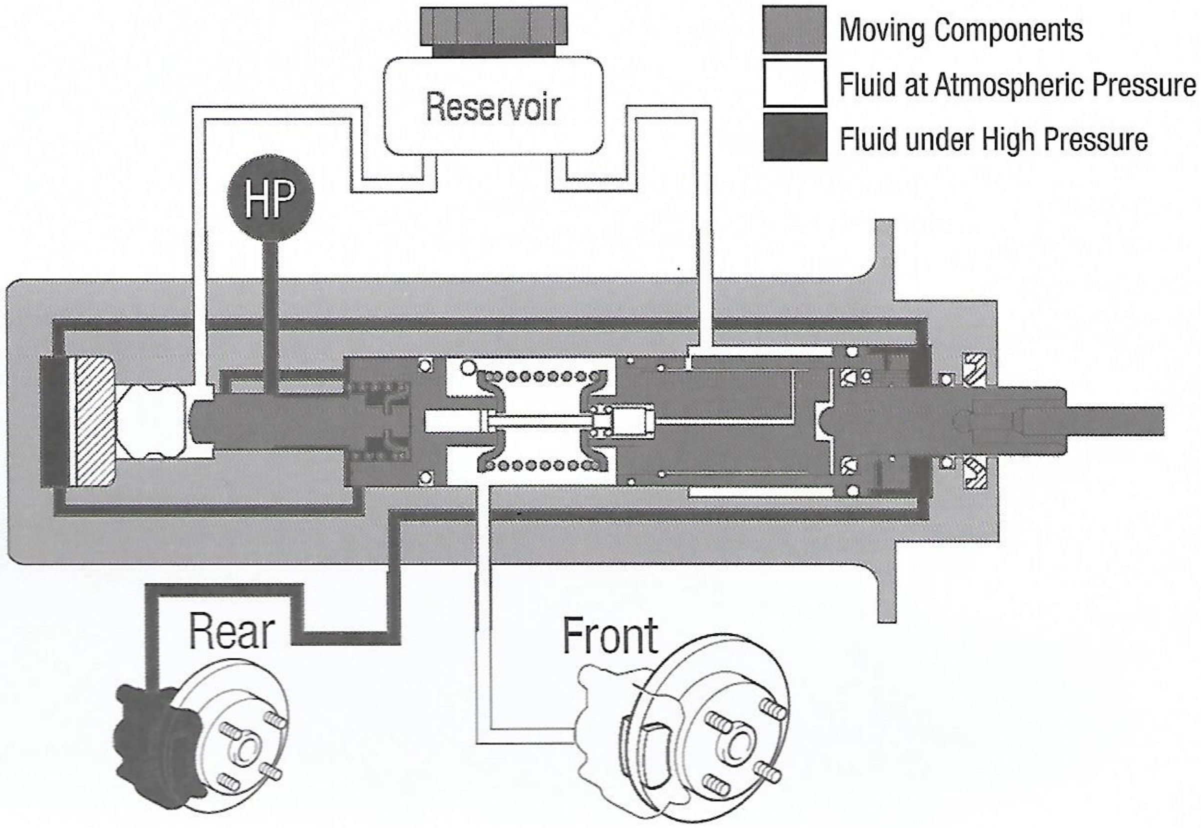
At Rest



When the Master Cylinder Assembly is 'At Rest' the Master Cylinder Return spring holds the Master Cylinder Piston at the return end of the bore, which in-turn holds the Brake Booster Piston at its return end of the bore. The Regulator Return Spring holds the Regulator Piston against its rest stop closing the High Pressure Fluid Feed Port with the Regulator Valve.

HYDRAULIC BRAKE BOOSTERS continued...

Braking (stage 1)



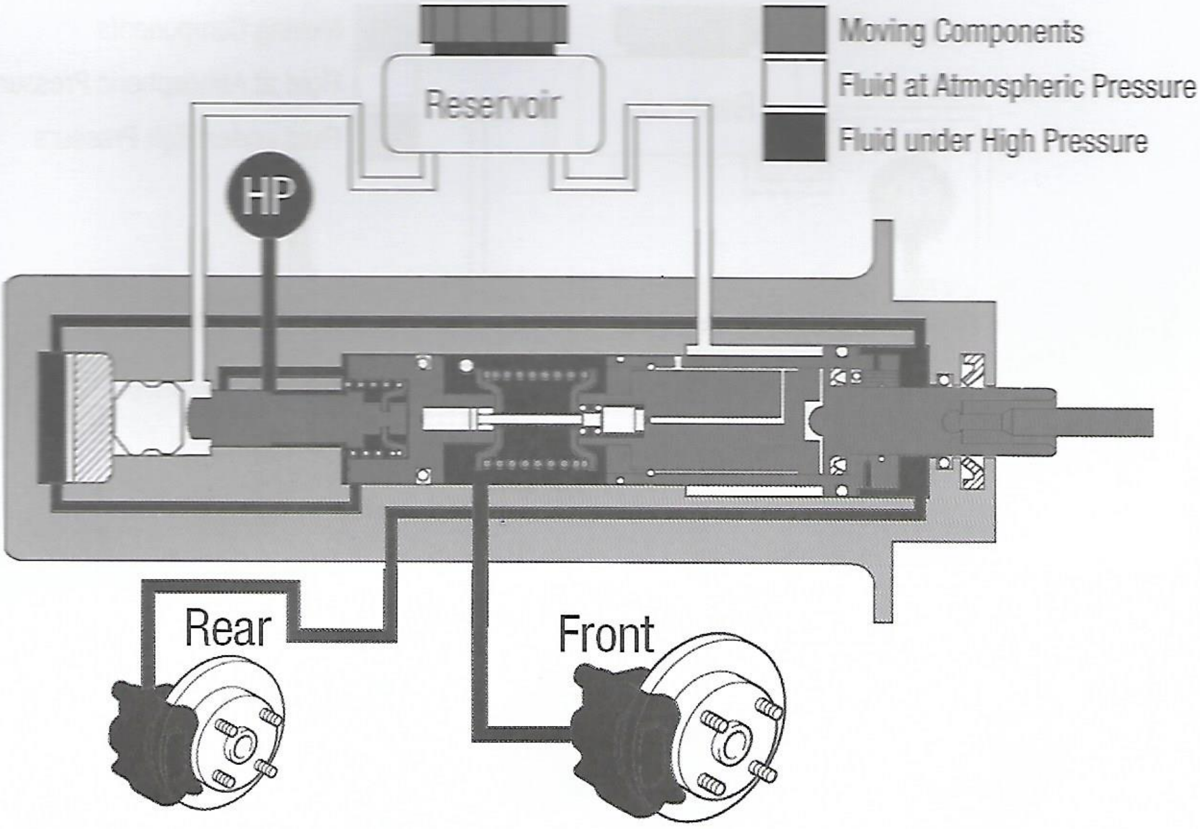
During the initial braking period there are so many different functions happening that it helps to look at the operation in two stages. In reality stage 2 follows stage 1 so closely that the two are happening simultaneously.

The first movement is initiated by the Brake Pedal, through the Push Rod, Power Piston and the Master Cylinder Piston. Because the Master Cylinder Return Spring is heavier than the Regulator Return Spring there is no fluid pressure increase in the Master Cylinder Chamber and the force is applied to the Regulator Valve, opening the High Pressure Fluid Feed Port. High pressure brake fluid is directed to the Brake Booster Chamber and to the Rear Brake Callipers.

At this point the rear brakes start to apply pressure and the pressure starts to react on the Brake Booster Piston. The rear brake circuit is controlled by the Regulator Valve and the High Pressure Pump.

HYDRAULIC BRAKE BOOSTERS continued...

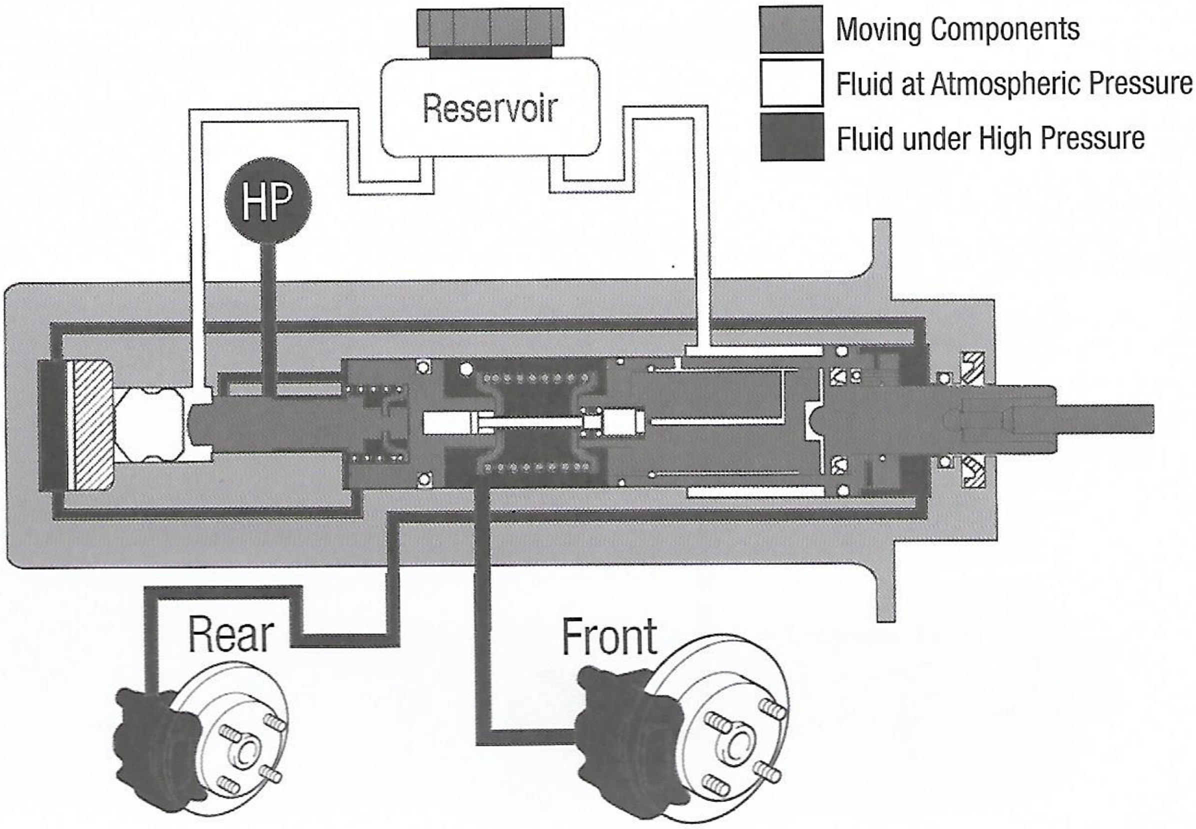
Braking (stage 2)


Moving Components
Fluid at Atmospheric Pressure
Fluid under High Pressure
Reservoir
HP
Rear
Front

As the Brake Pedal is depressed further the fluid pressure increases in the rear brake circuit and the Brake Booster Chamber. The Brake Booster Piston first chases, then pushes on the Master Cylinder Piston. This provides braking assistance and the pressure overcomes the Master Cylinder Return Spring. As the pressure increases in the Master Cylinder Chamber the front brake circuit is applied.

HYDRAULIC BRAKE BOOSTERS continued...

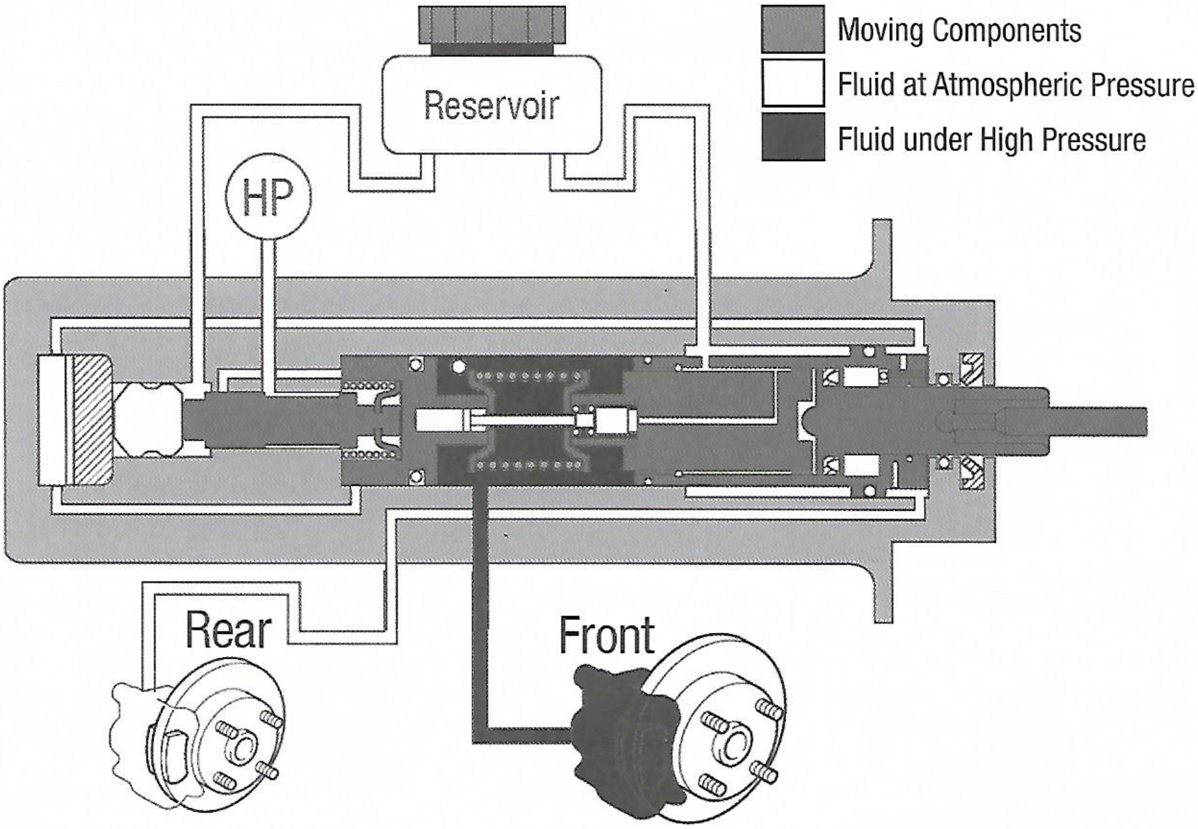
Heavy Braking


Reservoir
HP
Moving Components
Fluid at Atmospheric Pressure
Fluid under High Pressure
Rear
Front

During a heavier braking manoeuvre the increased pressure in the Brake Booster and rear brake circuit has an effect on the Reaction Disc and Piston. The higher the fluid pressure becomes, the more distorted the Reaction Disc becomes and the resistance to the Regulator Piston increases. It is the Reaction Disc that regulates the front to rear brake proportioning as well as providing some resistance that is transferred all the way back to the drivers foot.

HYDRAULIC BRAKE BOOSTERS continued...

High Pressure Supply or Rear Brake Circuit Malfunction



If a malfunction prevents either the creation or delivery of high pressure fluid from the Hydraulic Pump and Accumulator, the Master Cylinder will only apply the front brakes.

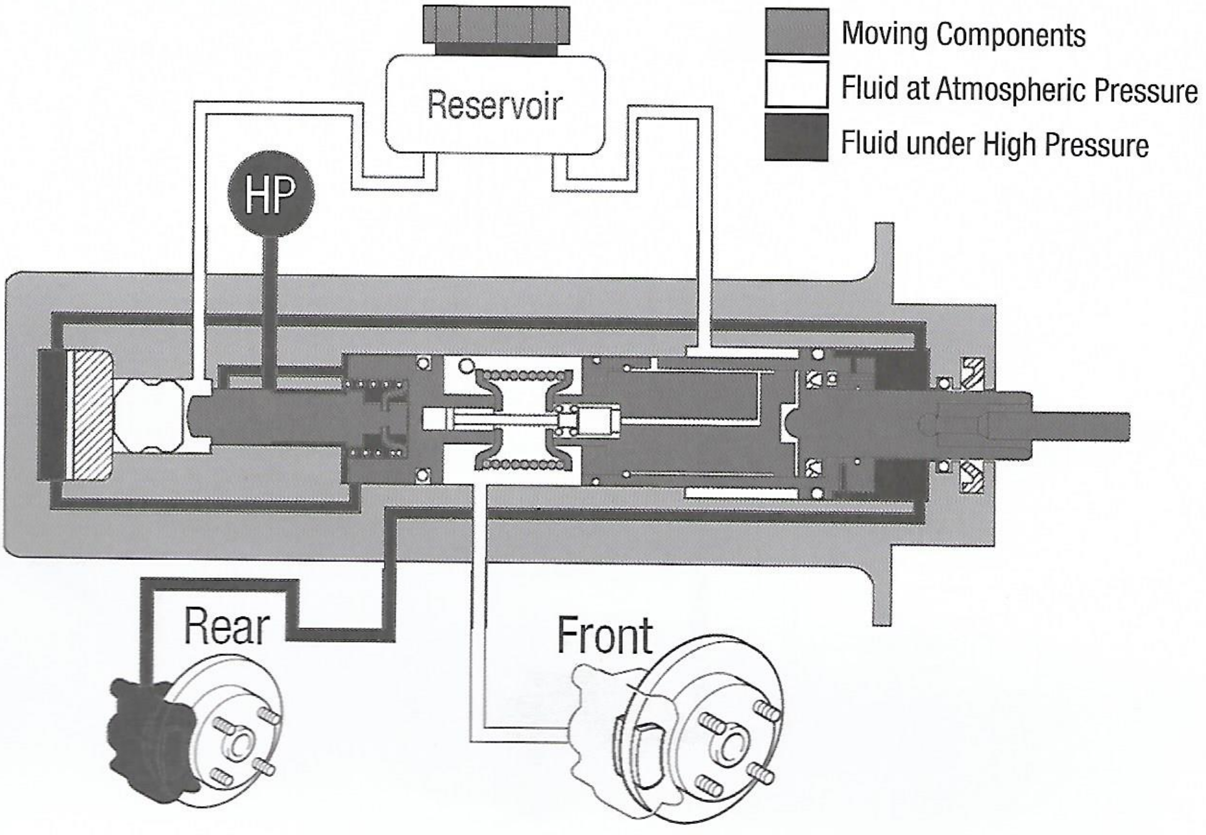
In the case of a rear brake malfunction allowing the loss of fluid, a pressure sensor will detect the loss of fluid and switch off the high pressure pump (as well as illuminating a variety of warning lamps). Resulting in an emergency braking situation the same as if the high pressure fluid supply had failed.

An emergency direct coupling of the master cylinder to the front brake callipers is achieved by using the smaller diameter Master Cylinder Piston. The inner sleeve of the Brake Booster Piston becomes the bore and the fluid pressure is created in the Master Cylinder Chamber without any booster assistance.

When this type of failure occurs the pedal effort is reduced and the travel is increased over normal operation. This is the opposite to the result of a vacuum booster failing.

HYDRAULIC BRAKE BOOSTERS continued...

Front Brake Circuit Malfunction



In the event of a Front Brake Circuit Malfunction where there is a loss of fluid, the initial braking would be unaffected ***(see: Braking - Stage 1)***. However, as the Master Cylinder Piston starts to compress the Master Cylinder Chamber there will be little resistance and the Master Cylinder Return Spring will fully compress. As the rear brakes are controlled by the Regulator Valve, rear brake application will operate normally.

Hydraulic Brake Booster Testing

1. Check the Battery Voltage
2. Pump pedal to deplete accumulator (up to 40 pumps)
3. Pedal reaction should DECREASE
4. Turn Ignition ON and check that the HBB Pump operates
5. Check operation with compatible Scan Tool
    - Raise vehicle
    - Release Parking Brake and shift to Neutral gear
    - Activate master solenoid – pedal should not move
    - Activate front solenoid – apply brake – only front should apply
    - Similar tests can be done for other VSC solenoids
    - ABS solenoids work in reverse
6. Carry out fluid pressure test

HYDRAULIC BRAKE BOOSTERS continued...

Servicing

When it comes to the Brake Bleeding Procedure it will vary depending on whether air has been able to enter the system or not. There are 3 different bleeding procedures that may need to be carried out:

- Brake Booster Bleeding
- Brake Line Bleeding
- VSC Valve Assembly Bleeding

Note: *For fluid change only (no air in system),only the Brake Line Bleeding Procedure (Part 1) is required!*

Brake Booster Bleeding Procedure:

1. Ignition ON until Hydraulic Brake Booster Pump cycles OFF
2. Ignition OFF
3. Depress the brake until assistance is lost
4. Repeat steps 1-3 five times.

Caution: *The Hydraulic Brake Booster Pump should cycle OFF within 18 seconds, if it takes longer repeat the Bleeding Procedure!*

Brake Line Bleeding Procedure (Part 1 of 2):

1. Carry out Brake Booster Bleeding Procedure
1. Ignition ON
2. To bleed the front brakes use the 'Pump and Hold' method, until the fluid is clear from air bubbles
3. Repeat on the opposite side
4. To bleed the rear brakes, depress and hold the Brake Pedal
5. Simply open the bleeder screw, until the fluid is clear from air bubbles
6. Repeat on the opposite side

Caution: *Be careful not to pump the reservoir dry, this is an easy mistake on the rear circuits!*

Brake Line Bleeding Procedure (Part 2 of 2):

1. Carry out Brake Line Bleeding Procedure (Part 1)
2. Connect a compatible Scan Tool
3. Ignition ON
4. Enter the Air Bleeding function in the Chassis > ABS/VSC/TRC menu
5. Follow the on-screen instructions in the following order Front Right (FR Line), Front Left (FL Line), Right Rear (RR Line) then Left Rear (LR Line)
6. Check and clear DTC's.

HYDRAULIC BRAKE BOOSTERS continued...

VSC Valve Assembly Bleeding Procedure:

Note: *The Vehicle Stability Control (VSC) Valve Assembly Bleeding Procedure only needs to be carried out if air has entered the VSC Valve Assembly!*

Caution: *Do not depress the Brake Pedal at any point during this procedure!*

1. Carry out Brake Line Bleeding Procedure
2. Connect a compatible Scan Tool
3. Ignition ON
4. Open both rear brake bleeding screws
5. From the Scan Tool menu, select:
   Chassis > ABS/VSC/TRC menu > Actuation Tests > VSC/TRC Solenoid (SRMF) and VSC/TRC Solenoid (SRMR)
6. The Hydraulic Brake Booster Pump will pump fluid out of the open bleeders for 2 seconds
7. Repeat steps 5 & 6 until the fluid is clear from air bubbles
8. Close both rear brake bleeding screws
9. Open one front brake bleeding screw
10. Repeat steps 5 & 6 until the fluid is clear from air bubbles
11. Close the front brake bleeding screw and open the brake bleeding screw on the opposite side
12. Repeat steps 5 & 6 until the fluid is clear from air bubbles
13. Close the front brake bleeding screw
14. Ignition OFF
15. Ignition ON
16. Check and clear DTC's.

Fluid Level Inspection:

1. Ignition OFF
2. Pump brake pedal until the accumulator is exhausted (40 pumps).
3. Check that the level is between the MIN & MAX
4. Top up/remove as necessary to MAX mark
5. Ignition ON
6. Level should drop about 10mm.

Section ii

Brake Fluid Pressure Testing

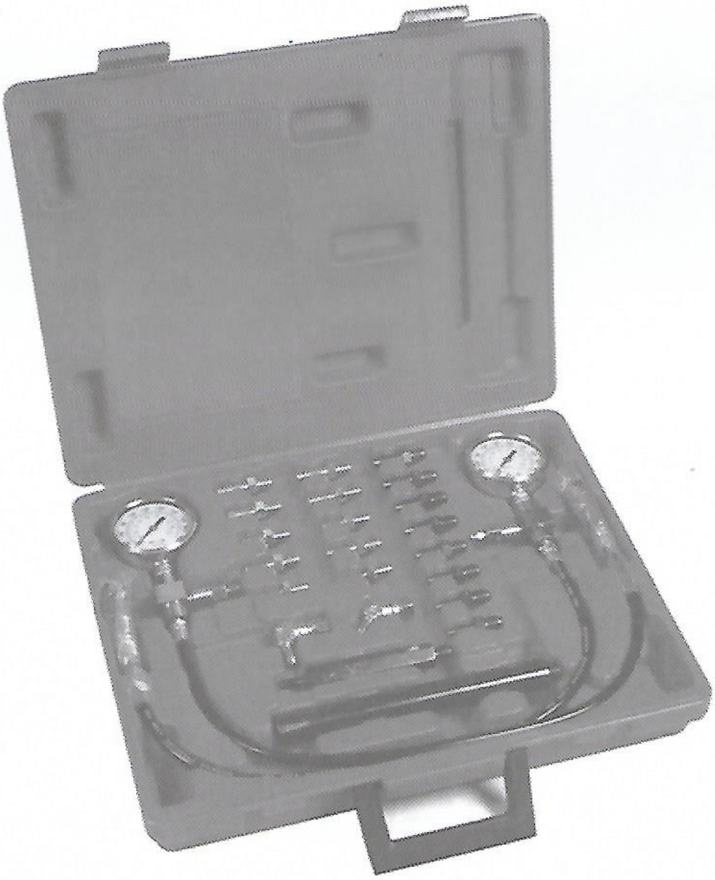
CONTENTS

INTRODUCTION

When you are presented with a vehicle that has any of the following braking conditions it can be difficult to accurately diagnose the cause:

- Hard Pedal
- Soft Pedal
- Poor braking performance
- Pulling while braking
- Diving while braking
- Wheel lockup during braking
- Uneven pad wear
- Excessive brake heat
- Booster efficiency

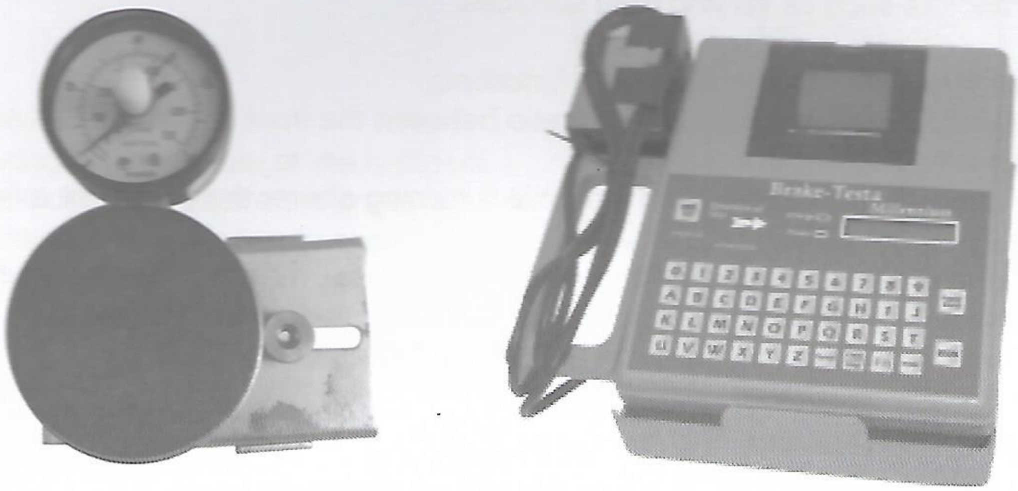
Many of these can be isolated with a little known but readily available tool...



Brake fluid pressure test gauges with a variety of fittings for different test procedures

INTRODUCTION continued...

Many manufacturers provide pressure specifications for maximum pressure with and without the boosters assistance. Some manufacturers go further and provide pressure correlation specifications for different pedal pressures (this requires a pedal force gauge)



A Kent Moore Brake Force Gauge is commonly recommended by vehicle manufacturers. However, if you have a Roadworthy Inspection type Brake Testa you can use it as a Pedal Force Gauge by selecting Function 5 (Fn+5)

BRAKE PROPORTIONING

Brake pressure gauges allow for accurate checking between left-right on any axle as well as front to rear axle brake-force distribution can also be checked, the pressure varies on the type of system employed…

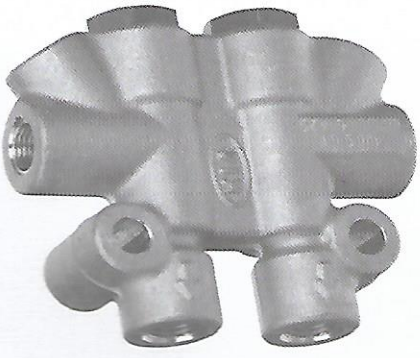
Proportioning Valves

Hydraulic Proportioning Valves

Provides equal pressure to front and rear except in emergency stop when rear pressure is limited to prevent rear wheel lock-up.

Load Sensitive Proportioning Valves

Usually connected to the rear axle of larger wagons, 4WD's and light commercial vehicles that have the ability to carry heavy loads.



Hydraulic Proportioning Valve

Load Sensitive Proportioning Valve

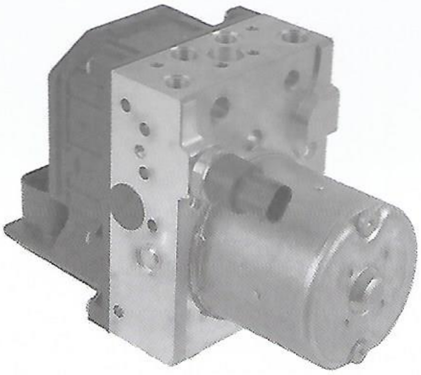
BRAKE PROPORTIONING continued...

Electronic Brake-force Distribution (EBD)
For vehicles fitted with Anti-lock Brakes (ABS) and/or Stability Control (VSC/ESP) the brake-force distribution can be done electronically by the ABS Modulator with input from the Wheel Speed Sensors (WSS). This allows the proportioning to adapt to other factors such as varying road surfaces.

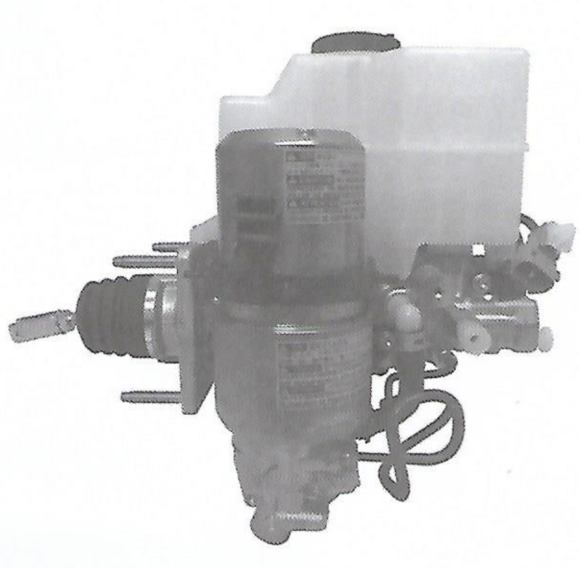
EBD functions differ slightly from ABS functions:

- The ABS ECU monitors the slip ratio between the front and rear axle using the Wheel Speed Sensors
- If the ABS ECU detects the rear axle is turning slower than the front axle it will activate EBD
- Some of the fluid pressure to the rear circuits is diverted to the accumulator
- Unlike ABS function, the ABS Pump is not engaged in EBD functions
- This means EBD may function even if the ABS is deactivated

Vacuum Boosted Systems
Proportioning is controlled with the ABS Modulator, using input from the WSS.



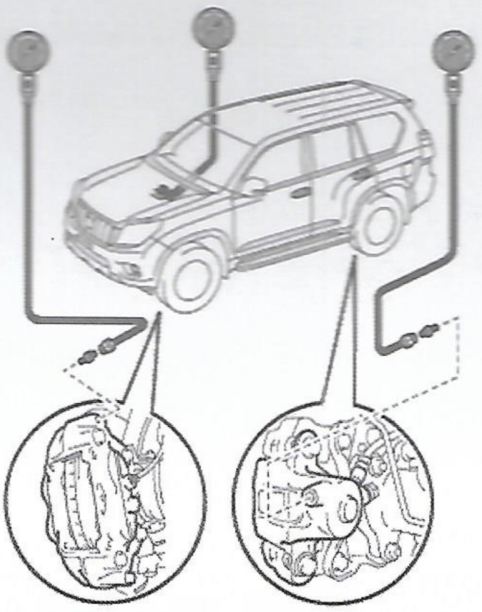
Hydraulic Boosted Systems
Rear brakes are not connected directly to the Master Cylinder. Rear brake force is controlled by solenoids from fluid stored under pressure in the Accumulator.



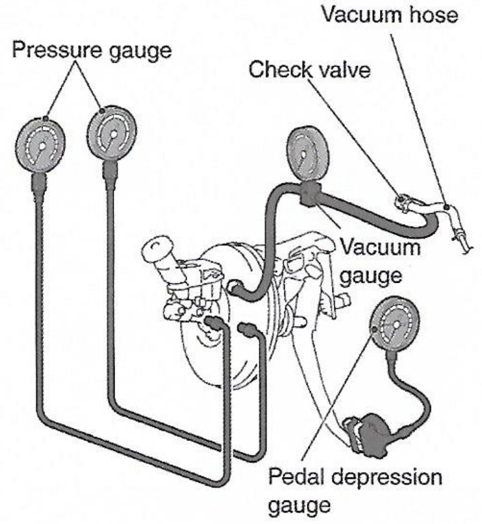
TESTING

It is possible to measure the brake fluid pressure at any union (joist) anywhere in the brake hydraulic system. Common connection points and test procedures include:

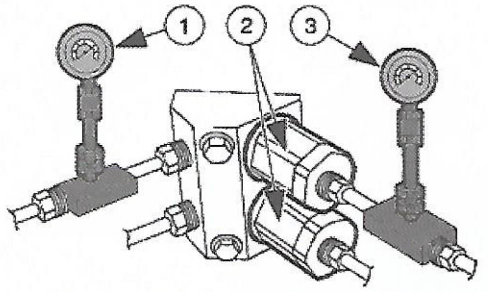
Measuring fluid pressure at the callipers. Many procedures require the pressures to be measured in relation to specific brake pedal force.



Measuring fluid pressure at the master cylinder. Some procedures require the brake booster vacuum to be monitored.


Vacuum hose
Pressure gauge
Check valve
Vacuum gauge
Pedal depression gauge

Measure fluid pressure before and after the proportioning valve.



1	Brake Fluid Pressure Inlet
2	Brake Pressure Control Valves
3	Rear Brake Pressure Outlet

TESTING continued...

Mazda

	2014 Mazda 3		2014 Mazda6	
Booster Vacuum	0 mmHg	500 mmHg	0 mmHg	500 mmHg
Brake Pedal Force	200 N			
Front Fluid Pressure	>640 kPa	>7,350 kPa	>460 kPa	>7,150 kPa
Rear Fluid Pressure				

Mitsubishi

	2011 Outlander			
Booster Vacuum	0 mmHg	0 mmHg	500 mmHg	500 mmHg
Brake Pedal Force	100 N	300 N	100 N	300 N
Front Fluid Pressure	>200 kPa	>1.8 MPa	6-8 MPa	>10.7 MPa
Rear Fluid Pressure				

	2014 KW Pajero					
Hydraulic Brake Booster Status	Depleted		ON			
Brake Pedal Force	100 N	500 N	100 N	200 N	400 N	500 N
Front Fluid Pressure (MPa)	>0.6	>4.5	3.0-4.0	8.0-10	14-18	15-19
Rear Fluid Pressure (MPa)	0	0	3.3-4.3			

TESTING continued...

Toyota

	2014 KDJ150 Prado					
Hydraulic Brake Booster Status	Depleted		ON			
Brake Pedal Force	245 N	343 N	49 N	98 N	147 N	196 N
Front Fluid Pressure (MPa)	>2.95	>4.2	1.6-2.8	4.2-5.4	6.9-8.1	9.5-10.7
Rear Fluid Pressure (MPa)	0	0	1.8-3.0	4.5-5.7	7.3-8.5	10-11.3

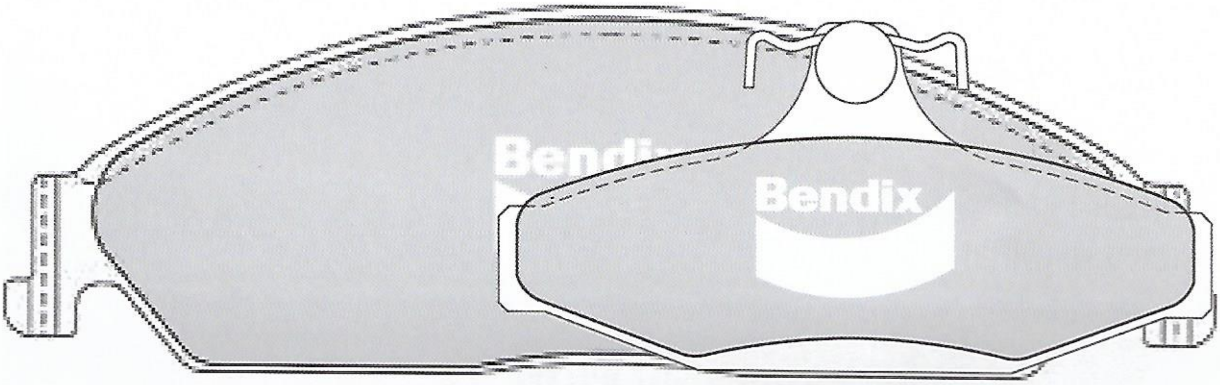
	2014 VDJ200 Land Cruiser					
Hydraulic Brake Booster Status	Depleted		ON			
Brake Pedal Force	245 N	343 N	49 N	98 N	147 N	196 N
Front Fluid Pressure (MPa)	>1.9	>2.8	1.1-2.3	6.1-7.3	11-12.2	16-17
Rear Fluid Pressure (MPa)	0	0	1.3-2.5	6.8-8.0	12-13.5	17.8-19

Note: *EBD will restrict rear fluid pressure if required!*

EXCESSIVE REAR BRAKE PAD WEAR

You have probably noticed in recent years that the rear brake pads are wearing much faster:

- As the pressure tests have just proven, rear brakes get equal or even higher brake force until slip ratio is exceeded
- Under light to normal braking rear brakes worker as hard or harder than the front brakes
- Rear brake pads are always smaller (sometimes substantially)
- Towing or carrying heavy loads reduces rear wheel slip therefore allows greater force to the rear.



To scale overlay of brake pads from an FG Falcon
Large pad is front, Small pad is rear (approx. 1/3 the friction area).

REAR DRUM BRAKES

WHY are some cars still using drum brakes?

- Greater friction area
- Reduced maintenance
- Less expensive because of Parking Brake integration
- Large parking brake (compared to drum in hat) increases towing capacity.

SPECIAL SERVICE TOOLS

Name	Part Number
Toledo Universal Brake Pressure Test Kit	310400
Kent-Moore Brake Pedal Effort Gauge	J28662
Circuitlink BrakeTesta (with pedal force transducer)	BTME or BTGPS

Section iii

Brake Fluid

CONTENTS

INTRODUCTION

Brake fluids have been causing confusion ever since a handful of vehicles that specified DOT 3 had a negative reaction to the new DOT 4 fluid. This first occurred back in 2006 but was not known to the greater industry until 2009. Until this point it had been widely accepted that DOT 4 fluid superseded and was backwards compatible for DOT 3 systems, we now know that is not completely correct.

There are many standards that apply to brake fluid globally. Historically the US Department of Transport (DOT) has been the predominant standard that has been used in Australian and New Zealand but things are changing. Strictly speaking the [US] Federal Motor Vehicle Safety Standard #116 (FMVSS 116) which issues the DOT specifications only dictates the performance, viscosity and boiling points for brake fluid. The Society of Automotive Engineers (SAE) is a US based association that coordinates the development of standards but does not issue or enforce them. The SAE standards are often referred to in other standards, such as DOT and also Manufactures Specific Standards.

Similar to the SAE is the International Organisation of Standardisation (ISO) which is a global network of standards organisations. As with the SAE, the ISO develops standards rather than enforcing them. Standards Australia (SA) and the New Zealand Standards Organisation (NZSO) represent their respective countries on the ISO board. ISO standards are also mentioned in many other standards including the AS/NZS 1960.1 Standard for Brake Fluid.

Because of the small to nonexistent manufacturing industries in Australia and New Zealand our standards are almost unheard of. However, they do exist and are sometimes found in the specifications of Australian manufactured vehicles. This allows local standards to reflect local conditions, this is evident in the AS/NZS 1960.1 Grade 1 which is based on DOT 3 but requires a higher dry boiling point.

Because there are minimum and maximum parameters for the different characteristics the following groups can be considered equivalent:

DOT 3
- J1703
- ISO 4925 Class 3
- AS/NZS 1960.1 Grade 1

DOT 4
- J1704
- ISO 4925 Class 4
- AS/NZS 1960.1 Class 2 & 3

DOT 5.1
- ISO 4925 Class 5.1

Note: *There are no equivalent standards by SAE, AS or NZS for DOT 5.1 and there is no equivalent for ISO 4926 Class 6 by any of the other standards!*

BRAKE FLUID TYPES

These comparisons are illustrated in the following table:

Specification		Min. ERBP	Min. WERBP	Min. Vis. 100°C	Max. Vis. -40°C
SAE	J1703	205°C	140°C	1.5cSt	1800cSt
	J1704	230°C	155°C		
FMVSS 116	DOT 3	205°C	140°C		1500cSt
	DOT 4	230°C	155°C		1800cSt
	DOT 5.1	260°C	180°C		900cSt
ISO 4925	Class 3	205°C	140°C		1500cST
	Class 4	230°C	155°C		1800cSt
	Class 5.1	260°C	180°C		900cSt
	Class 6	250°C	165°C		750cSt
AS/NZS 1960.1	Grade 1	230°C	140°C		1500cSt
	Grade 2	260°C	155°C		1800cSt
	Grade 3		170°C		

So...
There are two global standards SAE and ISO, the US DOT rating is most commonly used to categorise brake fluid types and most countries have their own standards. Here are some popular examples that you may see listed:

- Australia - AS
- New Zealand - NZS
- Germany - DIN
- Japan - JIS
- United States - DOT

BRAKE FLUID TYPES continued...

The next consideration are manufacturers standards. Many manufacturers have their own standards and in recent years some of these manufacturers have stopped listing DOT specifications for vehicles and only list their own product requirement. As they don't list the different characteristics required to meet the only 'correct' fluid is one that states the specific specification on the label.

The following table shows different manufacturers specifications and the ISO Class they apply too. The notes column provides a description of how the fluid may differ from the ISO Class. Where the cell has been left blank this information was not available.

Specification		Notes	ISO	Max. Vis. -40°C
Ford AU	ESZ-M6C55-A		Class 4	1400cSt
Nissan	NES-M5055			
Daimler AG	MB 331.0	+35°C above WERBP		
Holden	HN1796			
	HN2456	High RA requirement	Class 6	750cSt
GM	GMW3356			
Ford	WSS-M6C65-A2			
BMW Group	QV 34 001			
Volkswagen AG	VW 501 14 TL766-Z			
PSA Group	S71 2114			
JLR	4R83-M6C57 BH22-M6C57			
Renault	41.02.001 (4)			
Mazda	MN 120C			

Most manufacturers have not released why they do not list a standard fluid,
Mercedes Benz (MB 331.0) requires a higher minimum wet boiling point.
General Motors & Holden (GMW3356 & HN2456) require a higher minimum RA.
RA is Reserve Alkalinity and is the fluids ability to counteract acidity and maintain a pH higher than 7.

BRAKE FLUID CHEMISTRY

There are a few types of fluid, the type is defined by the Base Ingredient and its Chemistry.

FMVSS	Chemistry	Base	Min. ERBP	Min. WERBP	Min. Viscosity 100°C	Max. Viscosity -40°C
DOT 2	Organic	Castor Oil	190°C	140°C	N/A	N/A
DOT 3	Synthetic	Glycol Ether	205°C		1.5cSt	1500cSt
DOT 4		Borate Ester	230°C	155°C		1800cSt
DOT 5		Silicone	260°C	180°C		900cSt
DOT 5.1		Borate Ester				
LHM+	Mineral	Mineral Oil	249°C	249°C	6cSt	1200cSt

Organic
Castor Oil is an organic vegetable oil derived from the seeds of the Castor Oil Plant. These brake fluids were for pre-1950's vehicles that had natural rubber products. As these old systems would have had all of the rubbers replaced they can now use DOT 3 type fluids.

Mineral
Mineral Oil based brake fluids were used by Rolls Royce and Citroen, the latter using them in Xantia model cars until 2001. Mineral Oil does not absorb moisture (Hydrophobic) so it maintains its boiling temperature. However, if moisture does enter the system it will pool at low points. The water will boil if exposed to temperatures around 100°C which can cause the loss of brake pressure.

Synthetic
Synthetic brake fluids include Glycol Ether, Borate Ester and Silicone based brake fluids.

⚠ *Caution:* *People often attempt to differentiate DOT 5 from other fluids by describing it as "Synthetic" as you can see in the table DOT 3, 4, 5 and 5.1 are all Synthetic. Silicone based is the correct term to describe DOT 5!*

BRAKE FLUID CHEMISTRY continued...

Glycol Ether

J1703 (DOT 3) is the standard for Glycol Ether brake fluid. DOT 3 brake fluid does not contain Borate Ethers but equally it does not forbid the use of Borate Ester. This is the loophole that allows brake fluid manufacturers to state that DOT 4 fluid can also meet the DOT 3 standard. Although many DOT 3 designed brake systems have not experienced noticeable negative effects from using DOT 4 some components in some vehicles can have negative effects to the Borate Esters found in DOT 4 (more on this in the ***DOT 3 vs DOT 4 & 5.1*** topic).

Glycol Ethers are hygroscopic, meaning they absorb moisture. All rubber components within a brake system will allow microscopic amounts of moisture through the molecules in the rubber allowing the moisture content to slowly infiltrate the system and as this brake fluids is miscible the moisture will distribute itself evenly throughout the system.

Borate Ester

The main ingredient of J1704 (DOT 4 & DOT 5.1) fluids are Borate Esters which are not in DOT 3. Borate Esters have a significantly higher boiling point than Glycol Ether, to the point where they now meet and even exceed silicone characteristics. Like Glycol Esters they are Hygroscopic and miscible.

Note: *Glycol Ethers are also present in J1704 fluids!*

Silicone

J1705 (DOT 5) was first developed in 1985, with its silicone base it provided boiling temperatures significantly higher than the standard DOT 3 brake fluid that was the standard at the time. Because DOT 5 is hydrophobic it does not absorb moisture and maintains its boiling temperature. However, like Mineral Oil based fluids if moisture does enter the system it pools and can compromise the brake system.

- Most DOT 5 makers state that it is for Track Use Only
- They recommend the fluid is thoroughly flushed before each event
- They recommend the fluid is thoroughly flushed before storing the vehicle
- Use in normally maintained road vehicles could be very dangerous

BRAKE FLUID APPLICATION continued...

The previous pages have laid out the categories in which the common brake fluids are grouped by (largely due to which standard they meet). But the shelves in your local parts store have names like:

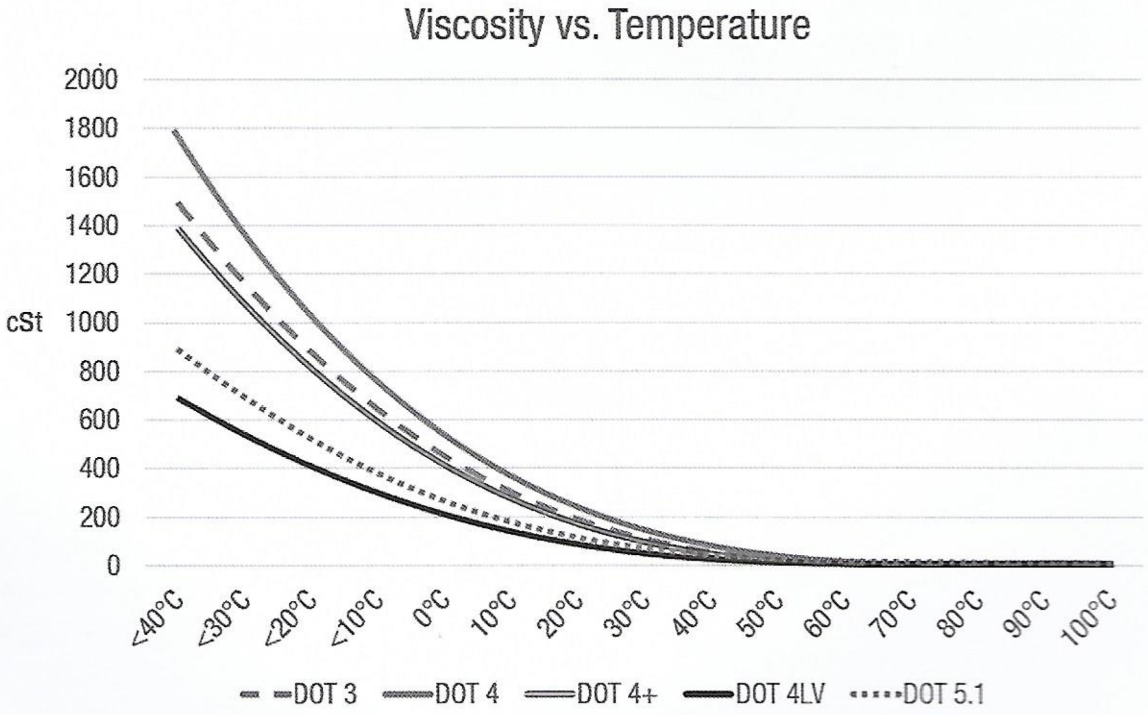
- Heavy Duty
- Super
- +Plus
- LV
- ESP
- Low Temp
- Racing

These additions to the DOT category usually reflect how at least one of the parameters (Boiling Point or Viscosity) has been exceeded. Other than that their true categorisation can be found listed under specifications on either the label or on the Product Information Sheet.

ISO 4925 Class 6

These brake fluids are what most new vehicles are required to use. Their key difference is their extremely low cold viscosity which is beneficial to the function of the stability control system (VSC/ESP) in cold conditions. For this reason these fluids usually have marketing names such as ESP, Low Temp or LV (low viscosity).

The following graph compares cold viscosity of various common fluids:



Kinetic Viscosity is measured in centistrokes (cSt)

BRAKE FLUID APPLICATION continued...

DOT 3 vs DOT 4 and DOT 5.1

The age old debate about the compatibility of DOT 3, DOT 4 & DOT 5.1 fluids is still confusing to many.

These are the facts:

- All DOT 3, DOT 4 & DOT 5.1 can be mixed together in a single container without any adverse reactions. So they are all compatible with each other. But this does NOT mean that all are compatible with the vehicles they are going in to.
- DOT 3 does NOT contain any Borate Esters
- DOT 3 does NOT ban the use of Borate Esters, that is why most DOT 4 and 5.1 products say they are suitable for DOT 3
- Borate Esters are primarily used to raise boiling point
- Borate Esters have friction modifying (reduction) properties
- Some Natural Rubber (NR) and Styrene-Butadiene Rubber (SBR) products swell excessively when in contact with Borate Esters
- Never put a lower DOT value than specified

Toyota vehicles

- OE specification is DOT 3 ONLY even for 2018
- Recall 2010/12082 blamed non-OE fluid for Master Cylinder failures
- DOT 4 has been claimed to cause a loss of brake pedal on vehicles with Hydraulic Brake Booster. In many cases flushing system with DOT 3 fixed the issue
- 2017 Toyota GT86 - DOT 3 spec
  2017 Subaru BRZ - DOT 4 spec
  Both of these vehicles have identical brake components

DOT 5.1

- DOT 5.1 was designed to provide a fluid with specs equal to DOT 5 but using a traditional Borate Ester base
- It has much lower cold viscosity properties than DOT 4 but not as low as ISO 4925 Class 6
- Technological advances have made it possible for DOT 4 fluids to be found with equally high boiling points
- DOT 5.1 is not specified by any Vehicle Manufactures

TESTING

Testing brake fluid is an important part of vehicle maintenance for both safety and serviceability. The brake fluid should be checked to ensure that it is still meets the minimum boiling point.

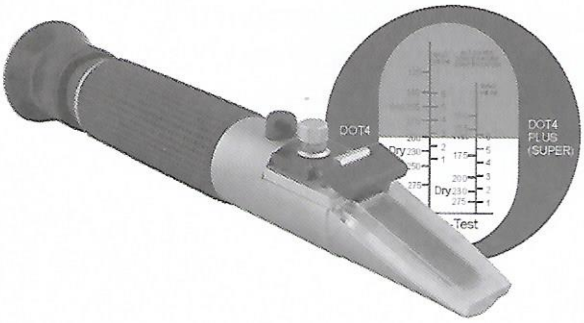
Boiling Point Testers

The preferred method for testing the boiling point of brake fluid is a Boiling Point Tester. These units physically test the point at which the fluid boils.

Boiling Point Tester

Refractometer

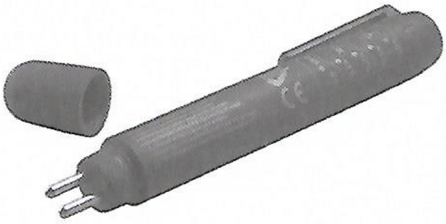
A refractometer will also provide an accurate reading of the water content. While it actually measures the water content, the scale provides an approximate cross reference to the impact on the boiling temperature. You will need separate refractometers for DOT 3 and DOT 4.



Refractometer

Conductance Tester

A conductance tester measures how easily an electrical pulse can be transmitted through the brake fluid. The theory is that the greater the water content the easier the signal will pass through. This method can be accurate however the conductance of new brake fluid varies between brands and grades of brake fluid. Therefore, in order for a conductance tester to provide an accurate reading it must be calibrated to a brand new sample of the same fluid that is being tested. This means that conductance testers are notoriously inaccurate and are known for failing brand new samples of brake fluid.



Conductance Tester

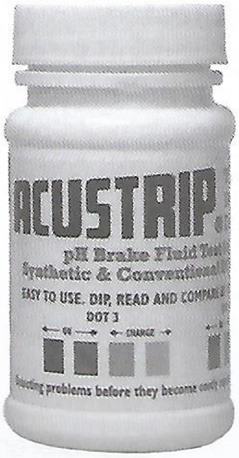
Caution: *Bendix, Castrol and Penrite have all issued bulletins stating that conductance testers are not appropriate for testing their products!*

TESTING continued...

Corrosion Test Strips

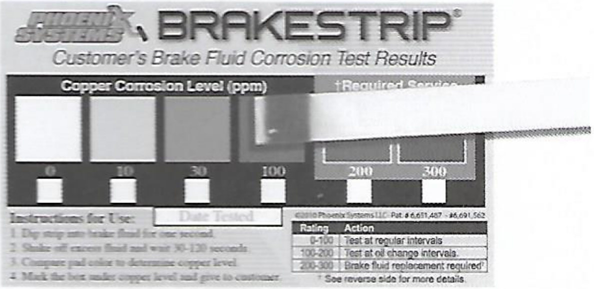
Another test is to measure for excessive corrosion within the system. As brake fluid deteriorates its acidity increases and it will start to eat away at the metals within the brake system, particularly the copper plating on the inside of the brake lines.

There are currently two types of test strips available online from the US that can keep track of the corrosion.


ACUSTRIP
pH Brake Fluid Test
Synthetic & Conventional
EASY TO USE. DIP, READ AND COMPARE
DOT 3
OK
CHANGE
problems before they become

pH Test Strips (Acustrip)

When the pH reading drops below 6 the fluid should be replaced.


PHOENIX SYSTEMS
BRAKESTRIP
Customer's Brake Fluid Corrosion Test Results
Copper Corrosion Level (ppm)
†Required Service
0
10
30
100
200
300
Instructions for Use:
Date Tested
Rating
Action
0-100 Test at regular intervals
100-200 Test at oil change intervals
200-300 Brake fluid replacement required†
† See reverse side for more details.

Copper Test Strips (Brakestrip)

These strips measure the amount of corrosion that has occurred, when copper content reaches 200ppm (parts per million) the brake fluid should be replaced.

SPECIAL SERVICE TOOLS

Name	Part Number
Sykes-Pickavant Brake Fluid [Boiling Point] Tester	335300
Endeavour Tools Brake Fluid [Boiling Point] Tester	ET8642
Circuit Link Brake Fluid [Boiling Point] Testa	CBFT
Brake Fluid Refractometer - DOT 3	
Brake Fluid Refractometer - DOT 4	
Acustrip pH Test Strips - DOT 3 & 4	ACU61000
BrakeStrip Copper Test Strips	3003

Section iv

Brake Hose Replacement

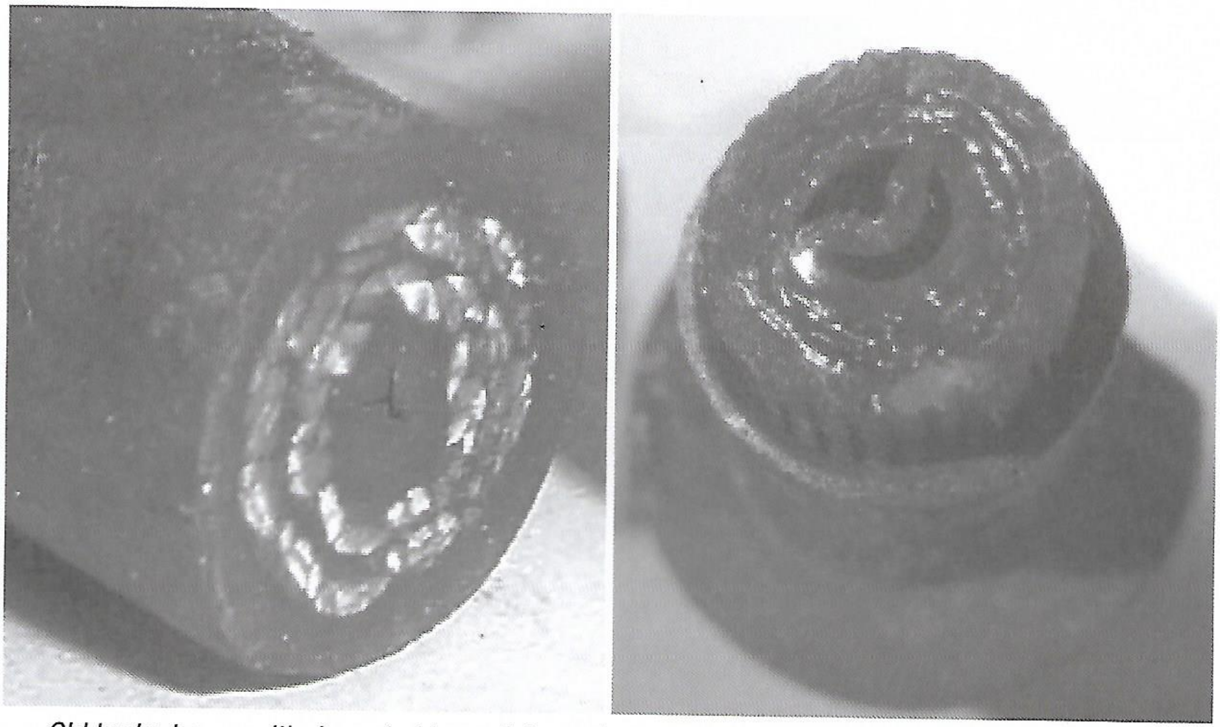
CONTENTS

INTRODUCTION

As a general rule, flexible brake lines (brake hoses) are designed to last the life of the vehicle (LOV):

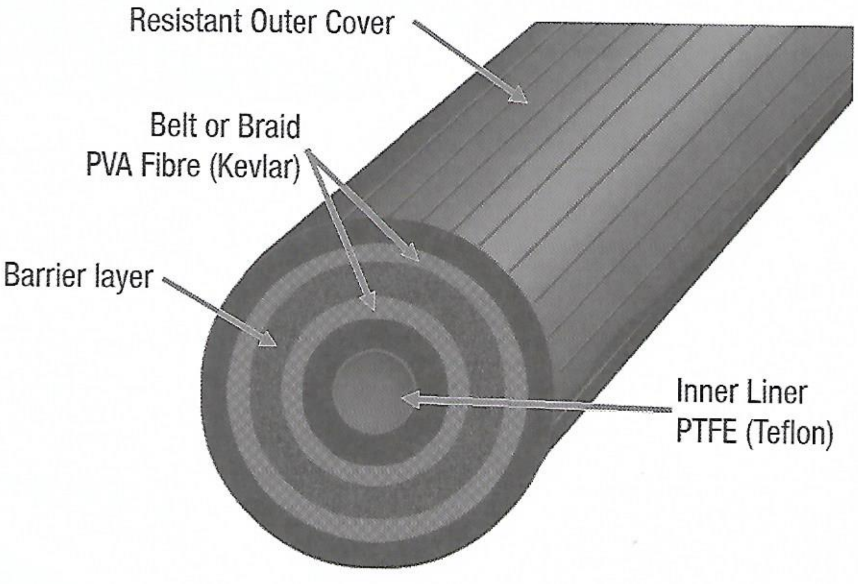
- Current LOV modelling is 15 years or 240,000km (min.)
- Pre-2004 LOV modelling was 5 years or 100,000km (min.)

They will degrade/ fail over time…



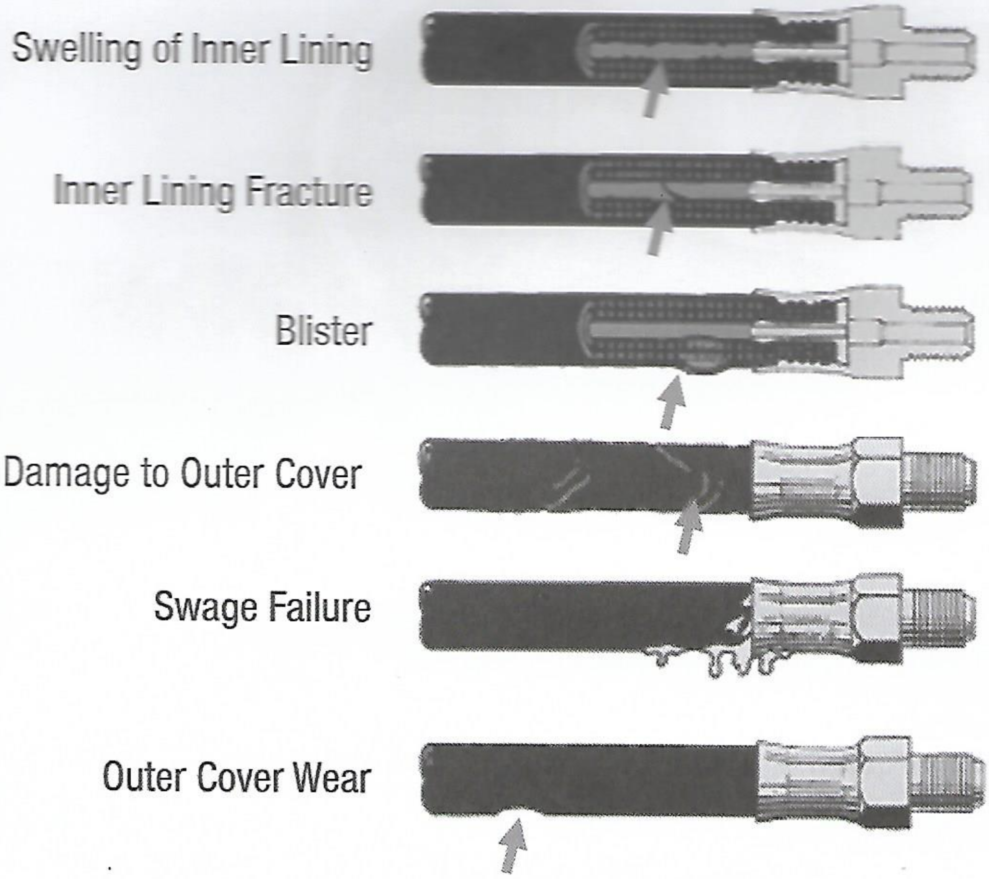
Old brake hoses with degraded inner linings, there will be no external indication of this failure.

CONSTRUCTION


Resistant Outer Cover
Belt or Braid
PVA Fibre (Kevlar)
Barrier layer
Inner Liner
PTFE (Teflon)

FAILURE TYPES

While external hose damage and failures are easily identifiable during routine maintenance, it is the internal failures that can be the most problematic and hardest to diagnose:



Swelling of the Inner Lining
Over time chemicals from and within the brake fluid penetrates the Teflon lining and it softens and swells. Swelling can be severe and extreme examples effectively close or block the hose completely. Less severe examples can cause reduced response time to brake pedal application and can cause brake release to be delayed.

Inner lining Fracture
Once the Teflon lining has softened it is susceptible to damage caused by an object striking the hose or by the use of a brake hose clamp. This can result in a piece of the lining tearing away and creating a one way (check) valve. When this occurs the brakes apply normally, but do not release (or release slowly) at the effected wheel.

Blister
A blister is evidence of a fracture in the inner lining and that pressurised fluid has entered into the braiding layer.

WARNING: *ALL HOSE FAILURES WARRANT IMMEDIATE REPLACEMENT!*

CHECKING FOR INTERNAL HOSE FAILURES

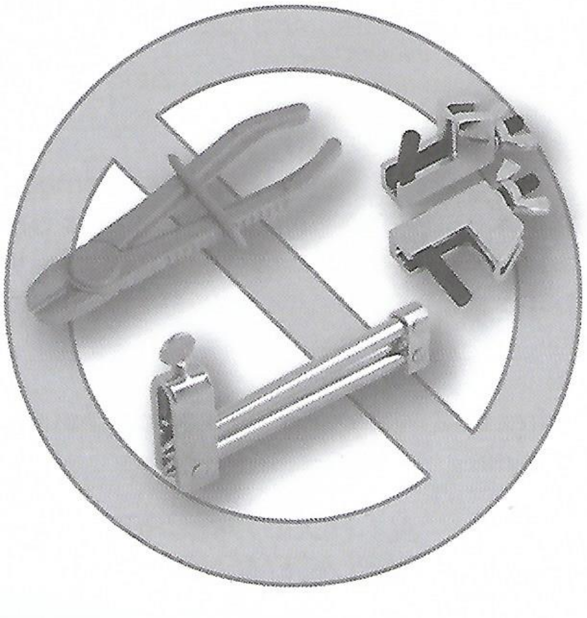
Trimmer
Line
CUTOR
ROUND
2.00MM X 28M
Ø 2mm

All standard brake hoses in Australia and New Zealand have a 3.2mm (1/8") internal diameter when new. Allowing for the reduced diameter of the unions/ferules a 2mm deburred trimmer line should pass freely through the length of the hose.

⚠ *WARNING:* *ALL HOSE FAILURES WARRANT IMMEDIATE REPLACEMENT!*

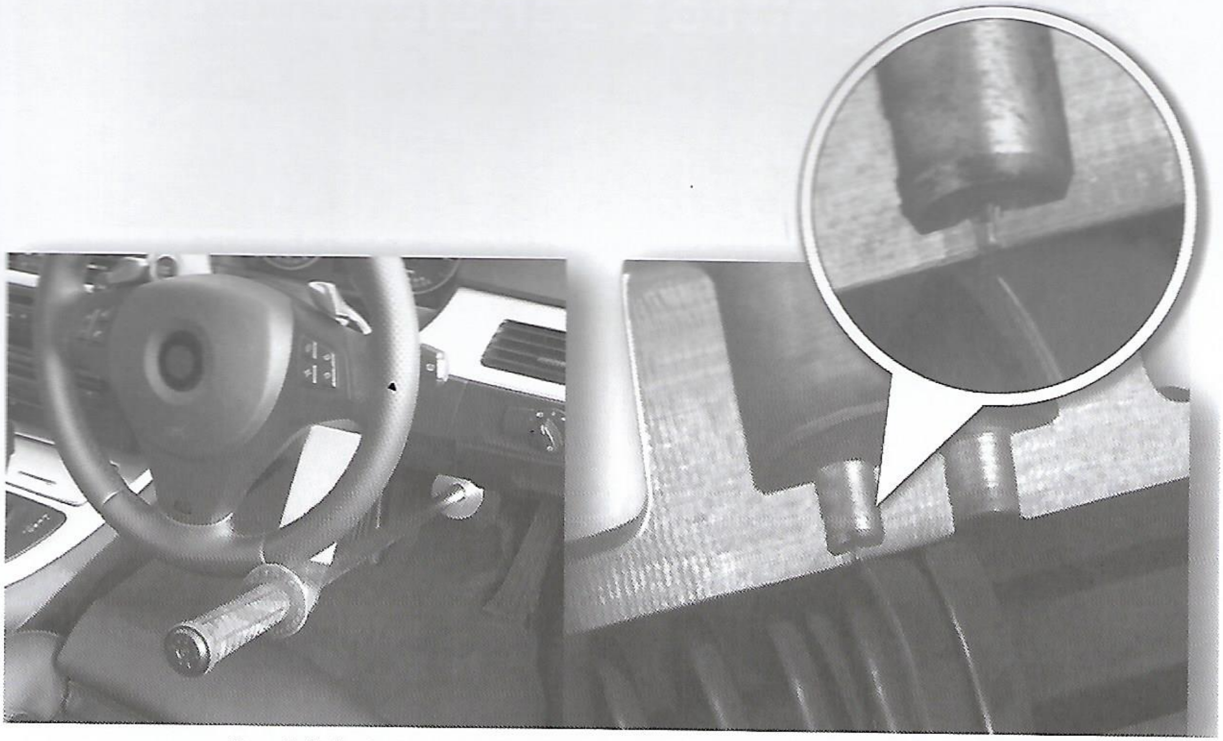
PREVENTING PREMATURE INTERNAL HOSE FAILURES

Excessive use and over tensioning of brake hose clamps can cause the inner teflon layer to fracture. Some manufacturers are discouraging the use of clamps for this reason.



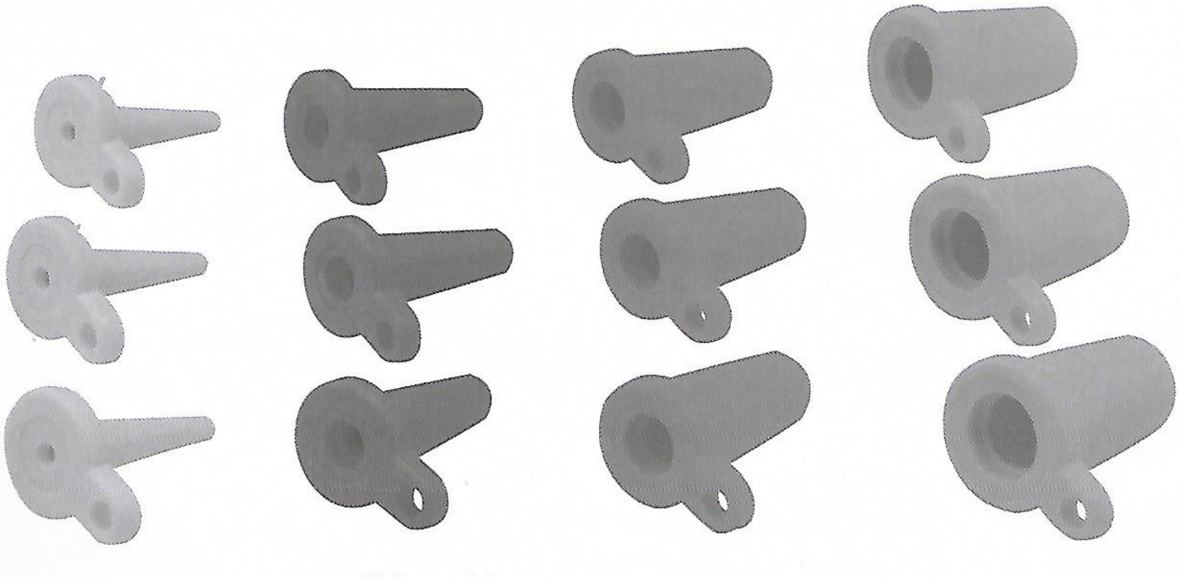
PREVENTING PREMATURE INTERNAL HOSE FAILURES continued...

Depressing the brake pedal a short distance will block the transfer port from the Master Cylinder to the Reservoir. This will prevent the brake fluid from siphoning out while disconnecting components on the brake system.



By slightly depressing the brake pedal the transfer port is closed

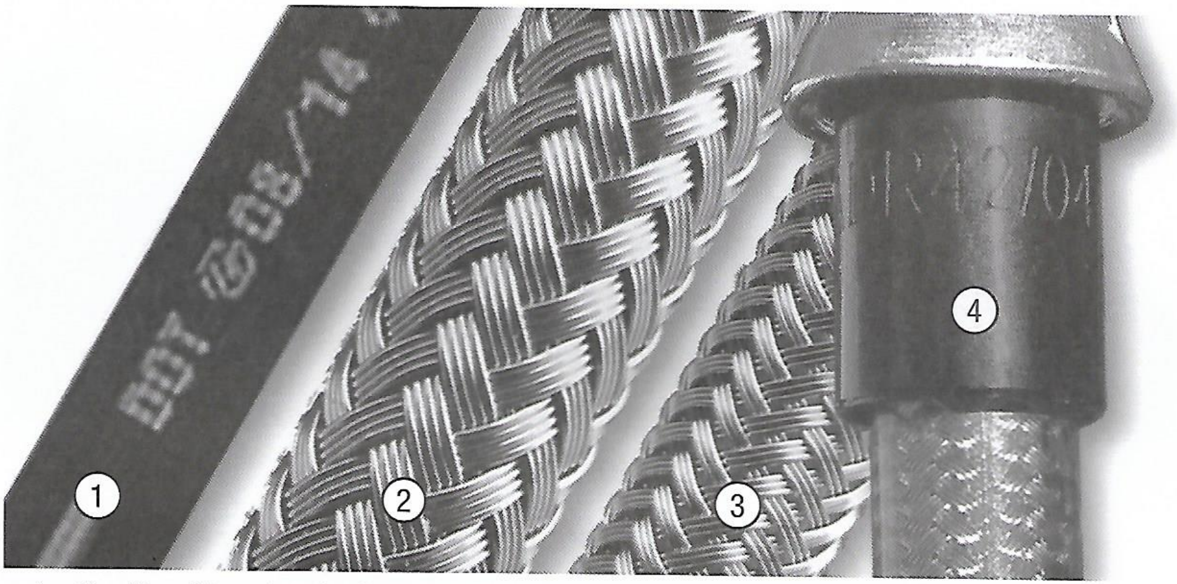
Assembly/Disassembly Plugs will also prevent siphoning as well as preventing debris from entering the hoses.



Universal Assembly/Disassembly Plugs

REPLACEMENT HOSES

- ADR 42/04 item 15. Brake Tubing and Brake Hose states:
  Hoses must conform to DS, DIN, ECE, ISO, JIS, SAA, SAE or FMVSS 106
- High quality brake hoses will have better reinforcement and provide a firmer pedal
- Stainless steel braiding can provide firmer pedal than rubber but the difference from quality rubber in negligible
- Often the improvement in pedal when stainless hoses are fitted is due to the old hoses being soft
- Not all stainless hoses are better than rubber -
- The inner liner is still PTFE (Teflon) so service life is the same
- Stainless braiding does provide greater protection against strikes



1. *Quality rubber sheathed brake hose with DOT (FMVSS 106) approval and date of manufacture*
2. *Stainless braided brake hose with dense weave*
3. *Inferior quality stainless braided brake hose with sparse weave*
4. *Stainless braided brake hose with ADR 42/04 approval on the collar*

SAE J1401 – 1/8" (3.2X10.5) –

Quality rubber sheathed brake hose with SAE J1401 approval

Caution: *Some states only allow approved brands of braided hoses, check with local authorities!*

SPECIAL SERVICE TOOLS

Name	Part Number
Hunter Brake Pedal Depressor	WA15-S

Section v

Performance Testing of Brakes

CONTENTS

INTRODUCTION

When it comes to testing brakes many workshops still rely on road testing and while a road test can provide good feedback to the tester of real-world performance it provides little hard evidence of brake performance.

Many Australian state government authorities require the use of a brake testing device that measures the vehicles deceleration. This provides the tester with a quantifiable value as to how well the brakes are slowing the vehicle.

Circuitlink
BrakeCheck
Brake-Testa

Performance Brake Testing provides a greater level of diagnostic information, the brake test physically measures the individual brake force at each wheel. This can identify when a single wheel or axle is not performing equally. There are two types of performance brake testers and each have their pros and cons.

Note: *Performance Brake Testers are expensive which means they are not for every workshop!*

Diagnostic Example

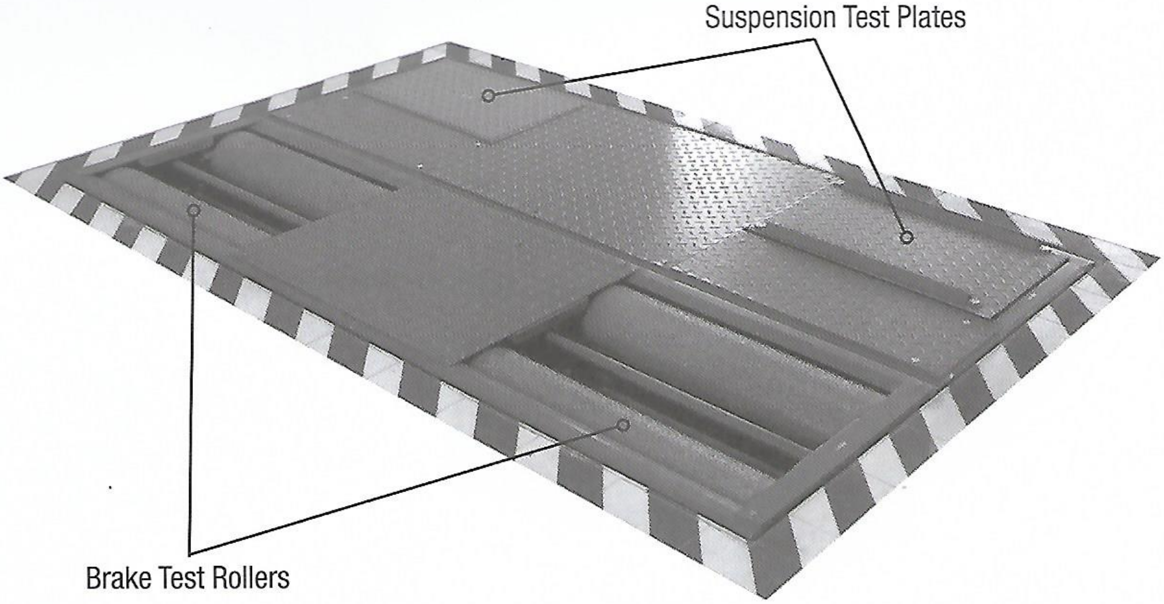
A single malfunctioning rear calliper that is providing little to no braking effort is unlikely to be noticeable on a regular road test or even on roadworthy type deceleration test. It would not be until the fault had been present for a significant amount of time that the uneven brake pad wear could be identified during a visual inspection. In this scenario the Performance Brake Testers would identify the fault as soon as it was present.

ROLLER BRAKE TESTERS

Rollers drive the wheels at approximately 5km/h and the brakes are applied to create resistance against the rollers. Brake judder is tested by lightly applying the brakes. The procedure is carried out on both the front and rear axles individually and the results are provided. Put simply, the roller brake tester is the reverse of a dynamometer.

Add on features include:

- Scales
- Suspension Test
- Wheel Alignment (side slip)
- Steering Test
- plus many more



One advantage of the roller brake tester is an ability to measure brake judder. Judder is identified by the varying deceleration rate during a brake test which also reduces overall brake efficiency. Another benefit is the ability to pinpoint low speed brake noises, knocking, rattles and squeals can be monitored from the safety of the workshop.

The stand alone Roller Brake Testers can test for:

- Brake Efficiency
- Brake Force Balance (Left-Right and Front-Rear)
- Brake Drag
- Brake Judder
- Park Brake (including electronic type)
- Rolling Resistance (Wheel Bearing etc)

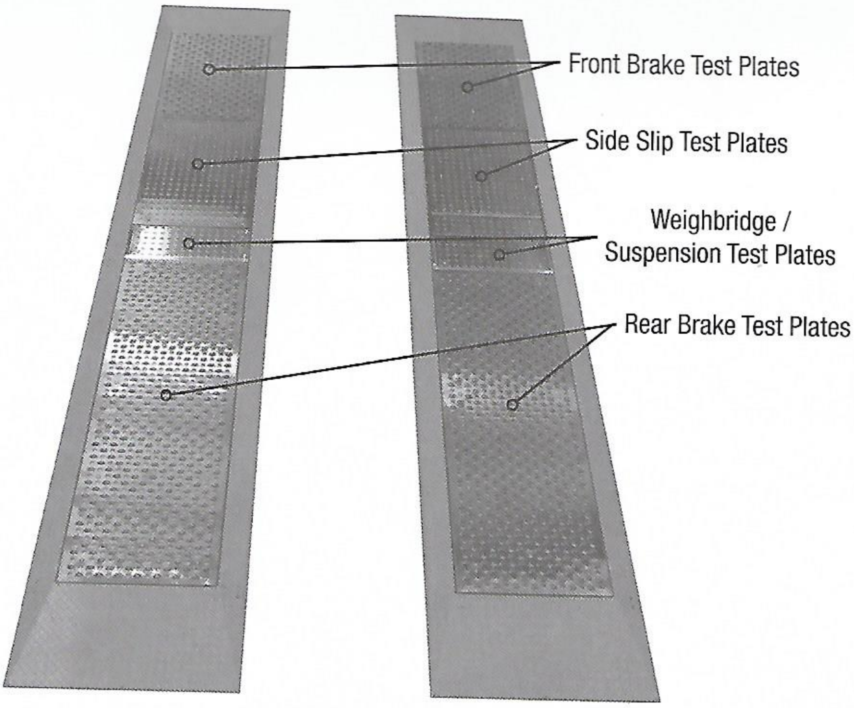
PLATE BRAKE TESTERS

When using plate testers the vehicle is driven onto the plates at approximately 5km/h and the brakes are applied, this forces the plates forwards against the load cells (sensors) which are measured and processed by a computer. All four brakes are tested in the single event.

Add on features include:

- Weighbridge
- Brake Pedal Effort Sensor
- Suspension Test
- Wheel Alignment (side slip)

Controller


Front Brake Test Plates
Side Slip Test Plates
Weighbridge / Suspension Test Plates
Rear Brake Test Plates

The plate type brake testers have the advantage of speed. The test procedure (brake and side slip) can be done in seconds making them great for high volume workshops.

The stand alone Plate Brake Testers can test for:

- Brake Efficiency
- Brake Force Balance (Left-Right and Front-Rear)
- Park Brake

SPECIAL SERVICE TOOLS

Name	Part Number
Circuitlink BrakeTesta Millenium	BTME
Circuitlink BrakeTesta GPS	BTGPS
Circuitlink BrakeCheck	BC1
Maha Roller Brake Tester	MBT2250
Safe-T-Stop Platetronic Brake Tester	Platetronic

Section vi

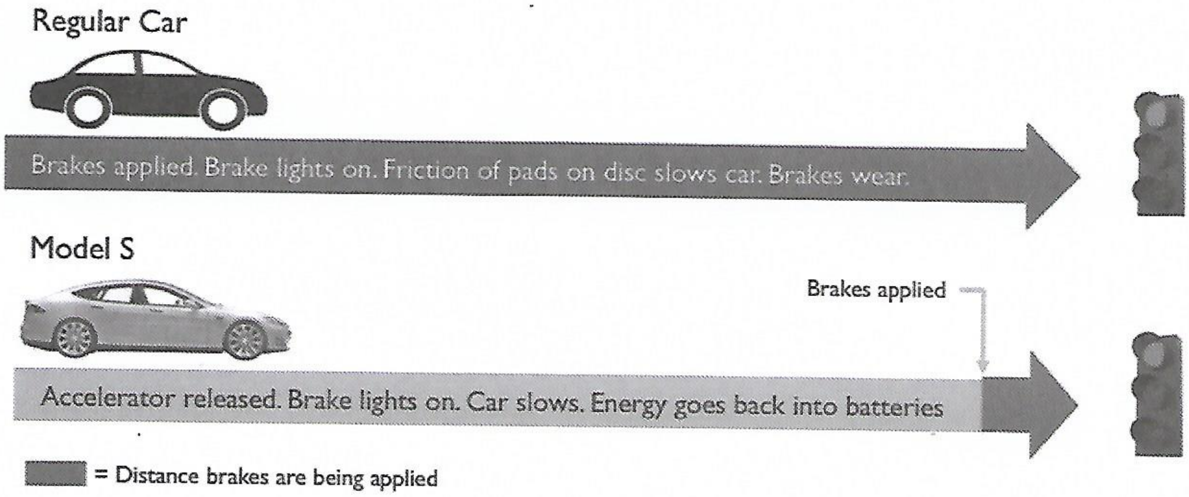
Hybrid and Electric Vehicle Brakes

CONTENTS

INTRODUCTION

Hybrid and electric vehicles must posses a braking system that meets global safety requirements as well as provide a variety of redundancies to stop the vehicle in an emergency situation. But in order to achieve the maximum driving range out of the vehicle they need to conserve energy and one way to do this is to turn the electric drive motors into generators for regenerative braking.

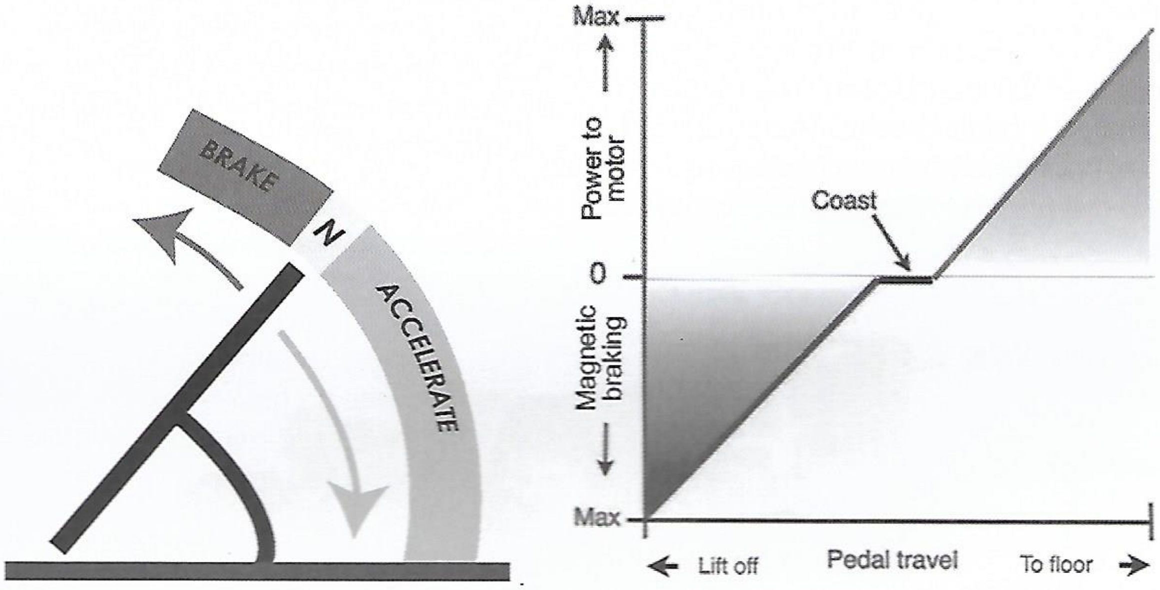
Regenerative braking does not replace traditional friction brakes but instead sits as a sort of middle ground between deceleration and friction braking. This can be done by dedicating the first part of the brake pedal stroke to regenerative braking by using a stroke simulator to provide pedal feedback and if greater braking force is applied the hydraulic system will then start to apply the friction brakes as required. For these systems the regenerative braking load is usually set to mimic an Internal Combustion Engine's (ICE) engine braking, but can be adjusted to be more or less aggressive on some vehicles.


Regular Car
Brakes applied. Brake lights on. Friction of pads on disc slows car. Brakes wear.
Model S
Brakes applied
Accelerator released. Brake lights on. Car slows. Energy goes back into batteries
= Distance brakes are being applied

Flyer for Tesla Model S regenerative braking system

Another method of controlling regenerative braking is through the activation of single pedal driving mode. Now before you expect to jump into one of these vehicles and find the brake pedal missing, this is not the case. This is purely a mode where the amount of regeneration braking is controlled by the releasing of the accelerator. The faster and further that the accelerator pedal is released the more aggressive the regenerative braking will become. This is also done with the assistance of the friction brakes as they are required.

INTRODUCTION continued...



BMW i3 Single pedal operation diagram

Single pedal driving is not necessarily new technology and a version was even offered on some ICE driven Mercedes Benz models during the mid-2000's as a feature of the Sensotronic Brake Control system. It is not a standard drive mode and is activated by the driver. Nissan call this feature "e-Pedal".

While all Hybrid and electric vehicles use some form of regenerative braking only a select few offer Single Pedal Driving Mode, these include:

- Tesla - All
- BMW - i3
- Nissan - Leaf (2018MY)

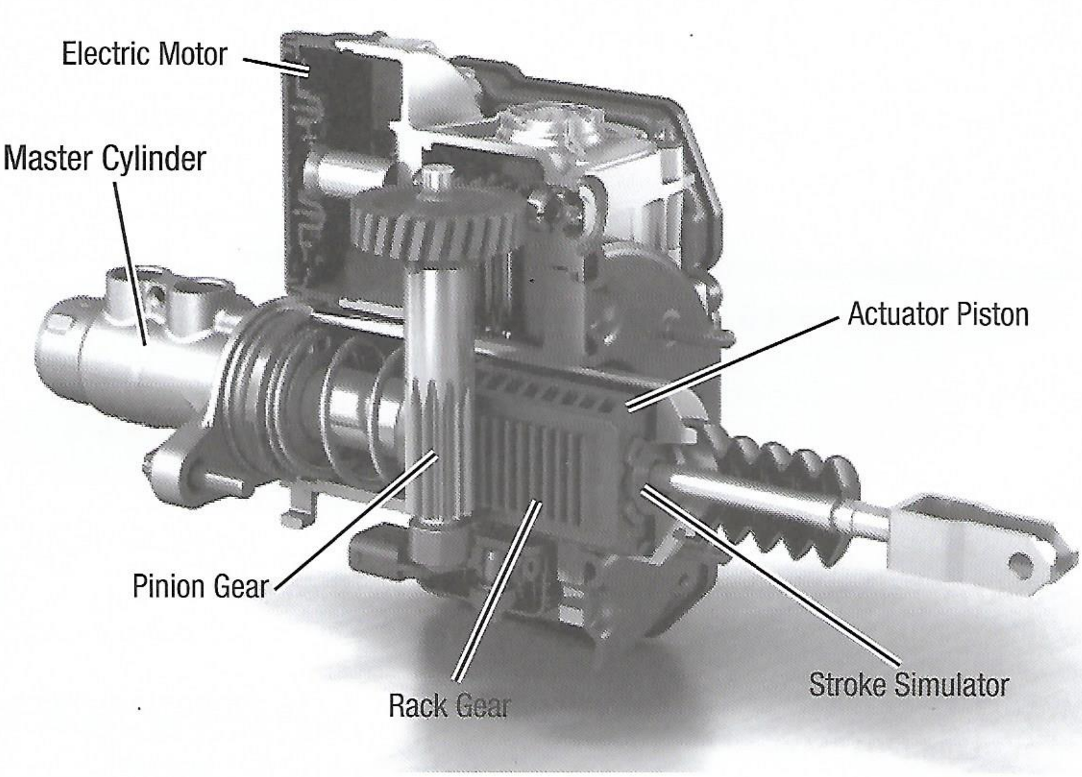
A regenerative braking system consists of:

- Brake Pedal
- Stroke (Brake Position) Sensor
- Stroke simulator
- ECU
- Motor/Generator
- Master Cylinder Assembly
- ABS/VSC/ESP Modulator
- Standard brake lines and brakes

Note: *Some components can be combined or separated dependant upon the vehicle requirements!*

TESLA

Tesla vehicles utilise an electro-mechanical brake master assembly. The assembly uses an electrically driven pinion gear to drive the rack gear on the outside of the master cylinder piston. The master cylinder piston applies the hydraulically controlled friction brakes. The stroke simulator located inside the master cylinder piston provides brake pedal response but also provides a link between the brake pedal rod and the hydraulic master cylinder for fail-safe operation.

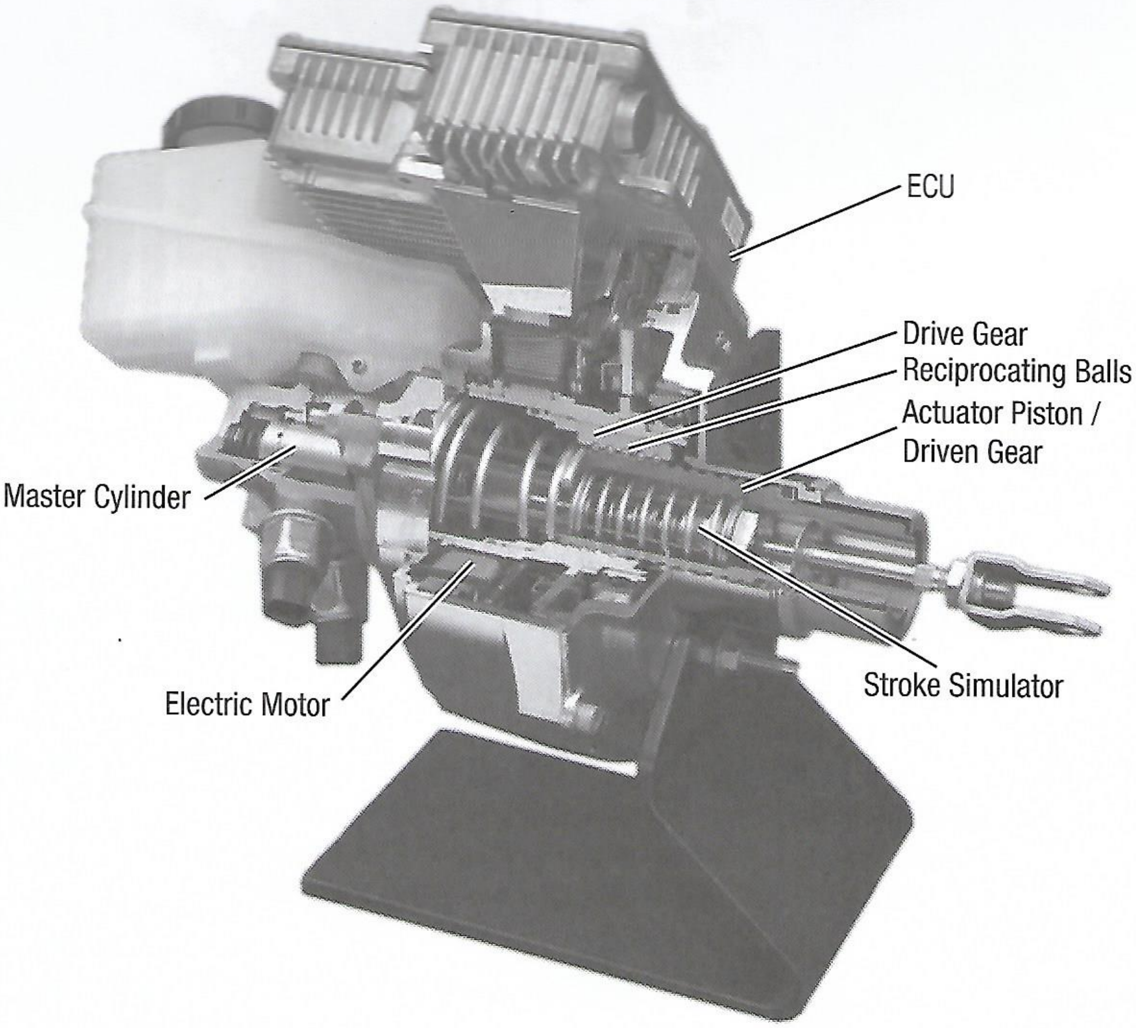

Electric Motor
Master Cylinder
Actuator Piston
Pinion Gear
Rack Gear
Stroke Simulator

Tesla's Electro-mechanical Brake Master Assembly (AKA: Bosch iBooster)

Note: *The Bosch iBooster is also used in the 2017MY Honda Civic Plug in Hybrid!*

NISSAN LEAF

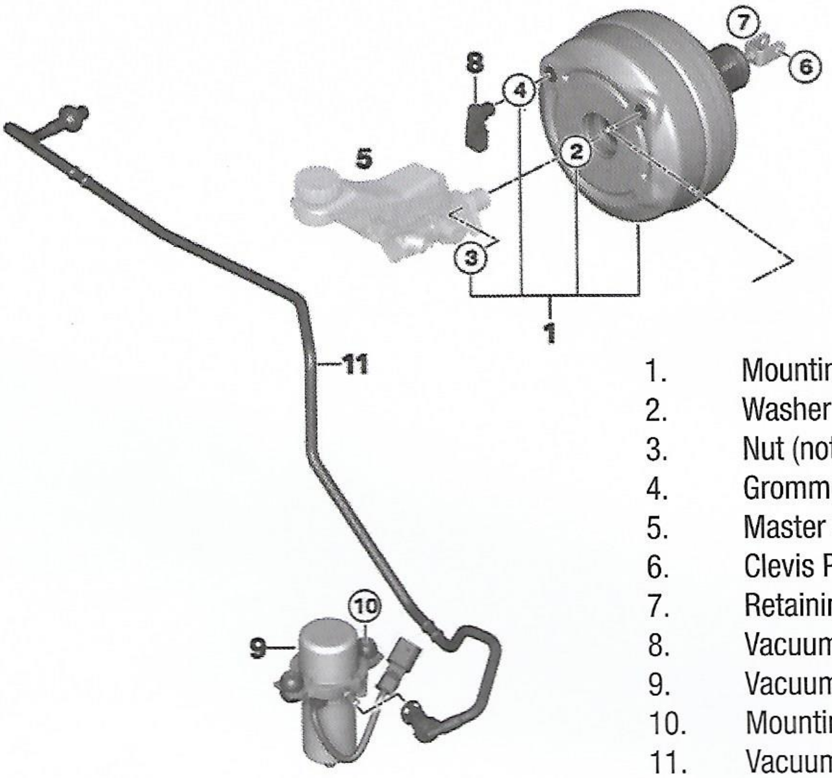
Nissan's brake master assembly employs a similar design and is called the Electric Driven Intelligent Brake (EDIB) and is designed and manufactured by Hitachi. It is an electro-mechanical brake master assembly. The EDIB uses an electric motor and reciprocating ball gearbox to control brake application. Pressure sensors provide feedback to the ECU. In the case of a fail-safe situation the Leaf has its own dedicated backup battery located within the Power Control Unit behind the back seat to drive the Brake Booster Motor.


ECU
Drive Gear
Reciprocating Balls
Actuator Piston / Driven Gear
Master Cylinder
Stroke Simulator
Electric Motor

Nissan/Hitachi Electric Driven Intelligent Brake (EDIB)

BMW i3

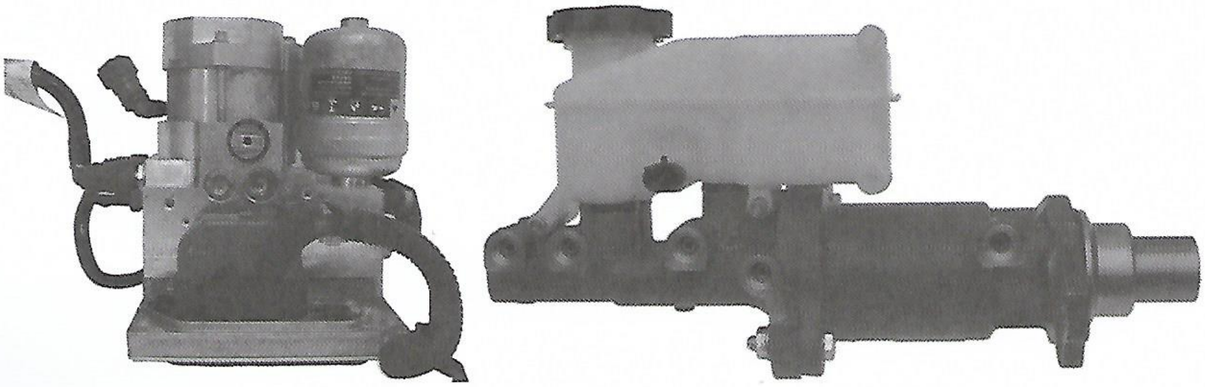
As the odd one out, BMW maintains the use of a traditional brake master cylinder and vacuum brake booster. Instead it utilises the VDC/ESP Controller for Single Pedal Brake application. This operates in exactly the same way as Active Cruise Control except the accelerator pedal is the input. As the electric motor drives the rear wheels of the i3 regenerative braking is limited to less aggressive operation.



1. Mounting Kit
2. Washer (not shown)
3. Nut (not shown)
4. Grommet (not shown)
5. Master Cylinder
6. Clevis Pin (not shown)
7. Retaining Clip (not shown)
8. Vacuum Sensor
9. Vacuum Pump
10. Mounting Bolt (not shown)
11. Vacuum Hose Pipe

HOLDEN VOLT

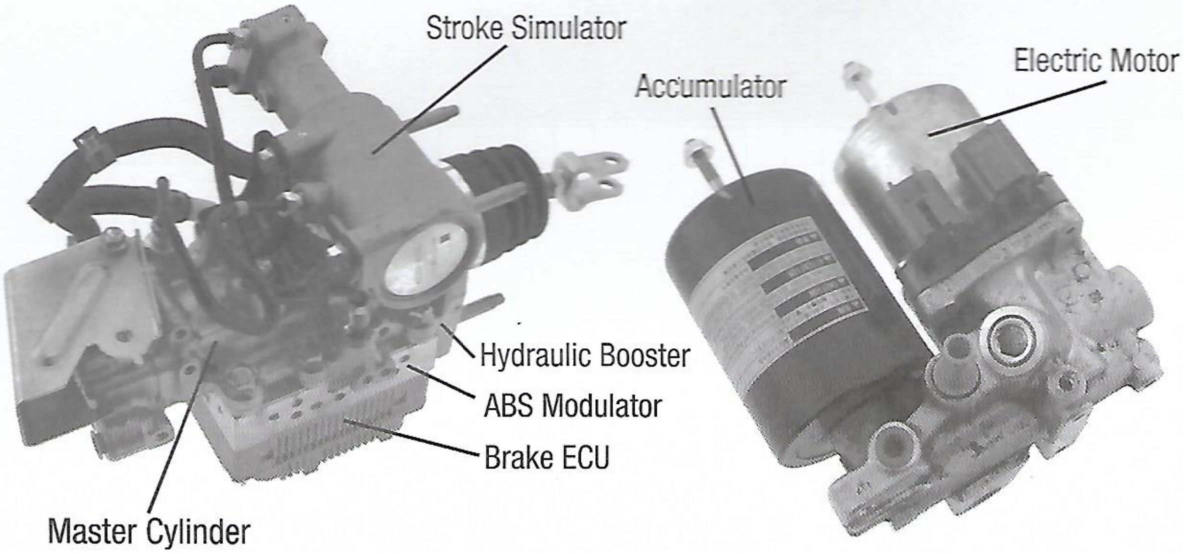
The Volt uses an Electro-Hydraulic Brake Booster which is effectively the same as the Toyota Electro-Hydraulic Brake Booster except that the Hydraulic Pump/ Accumulator and Master Cylinder/Booster are two separate assemblies.



Holden Volt ABS Modulator with Hydraulic Pump & Accumulator (left) and Master Cylinder and Booster assembly (right)

TOYOTA PRIUS

The Toyota Prius also utilises a system that operates similarly to the other non-hybrid Toyota's with Electro-Hydraulic Brake Booster (HBB) except that the Hydraulic Pump/Accumulator and Master Cylinder/Booster are two separate assemblies and with the addition of a Brake Stroke simulator.



REPLACING BRAKE PADS

The following method is required for 2001-2009 model Toyota Prius but is good practice for all hybrid and electric vehicles.

In order for the Brake ECU to control the balance between regenerative braking and friction (hydraulic) braking it requires feedback from multiple pressure sensors located on the Master Cylinder and in the ABS/VCD/ESP Modulator. To prevent a DTC being logged it is necessary to:

1. Remove the key from the ignition (or from the area if the vehicle is keyless start) before servicing the brake
2. Replace the brake lining as per your normal method
3. Slowly pump the pedal to move the pistons against the new pads
4. Ensure that a firm pedal is achieved
5. Turn the ignition ON.

Section vii

Brake by Wire Technology

CONTENTS

INTRODUCTION

The progression into Brake By Wire (BBW) has been slow but this doesn't mean that the big players haven't been working on technologies to implement. How far the technology has progressed depends on what your understanding of BBW is...

One definition suggests that BBW simply means that the application of the brakes can be applied without the use of mechanical force upon a brake pedal and hydraulic master cylinder. To this definition the Single Pedal Operation as discussed in the previous chapter (***Hybrid and EV Brakes***) is a Brake By Wire function. Active Cruise Control (ACC) would also be defined as BBW and Electronic Parking Brakes (EPB) could also be considered as such.

Another definition of BBW is that it requires the complete removal of the hydraulic system and the implementation of Electro-Mechanical brakes. If you choose this second definition then this technology is still a way from fruition.

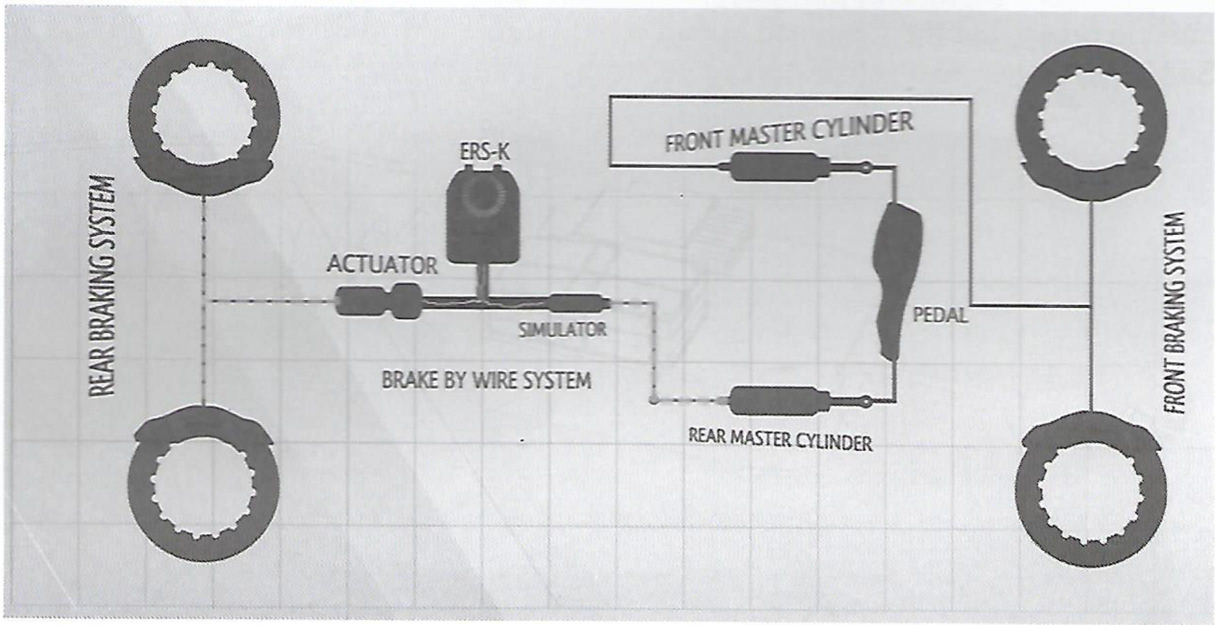
As with all emerging technologies the reality is going to fall somewhere between the two extremes.

Why should cars have BBW:

- The hydraulic force takes approximately 300-500ms to transfer from the brake pedal to the callipers. Electronic callipers can reduce that reaction time to 90ms
- Current ABS/VDC/ESP systems electronically actuate hydraulic valves to provide intervention, these systems can be simplified as the electronic calliper actuators are pulsed directly as required
- Reduced maintenance
- Brake Pads can be retracted away from the disc rotors, improving fuel economy and reducing wear

FORMULA 1

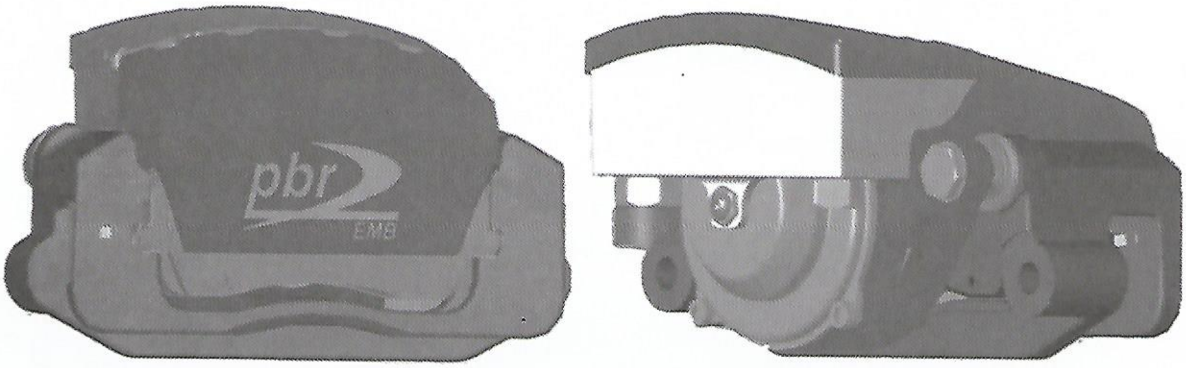
Current F1 BBW systems are actually less technical than most hybrid and EV braking systems. Of course much of this is due to race rules rather than technological limitations.


REAR BRAKING SYSTEM
ERS-K
ACTUATOR
SIMULATOR
BRAKE BY WIRE SYSTEM
FRONT MASTER CYLINDER
PEDAL
REAR MASTER CYLINDER
FRONT BRAKING SYSTEM

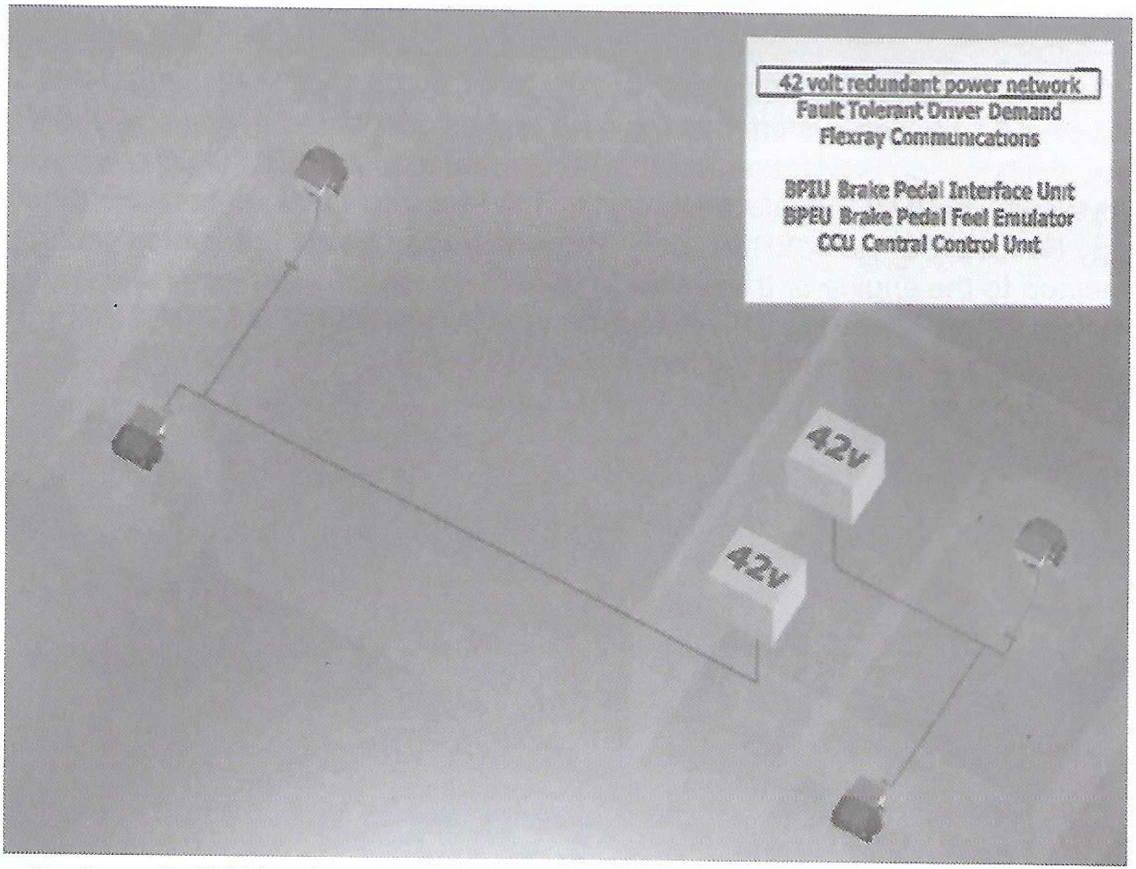
The typical F1 braking system has the front brakes connected hydraulically to the master cylinder, the rear brake circuit is connected to a simulator which converts the hydraulic force into an electrical signal. The simulator feeds data to the Kinetic Energy Recovery System (ERS-K or KERS) which uses an electric motor/generator connected to the engine or transmission to convert torque into electrical energy to store in a battery. Once the ERS-K has reached its threshold the ERS ECU controls a hydraulic actuator to apply the rear brakes.

PBR ELECTRO-MECHANICAL BBW

In 2007 PBR Australia designed and manufactured a full brake by wire system that had no hydraulics. The system used a 42 Volt power supply and Flexray data network to control the Electro-Mechanical Brake Callipers at each wheel, the callipers were capable of producing 40,000 Newtons of force with an integrated parking brake, but the response speed wasn't published. Only two Chevrolet Sequel hydrogen fuel cell prototype vehicles were ever produced.

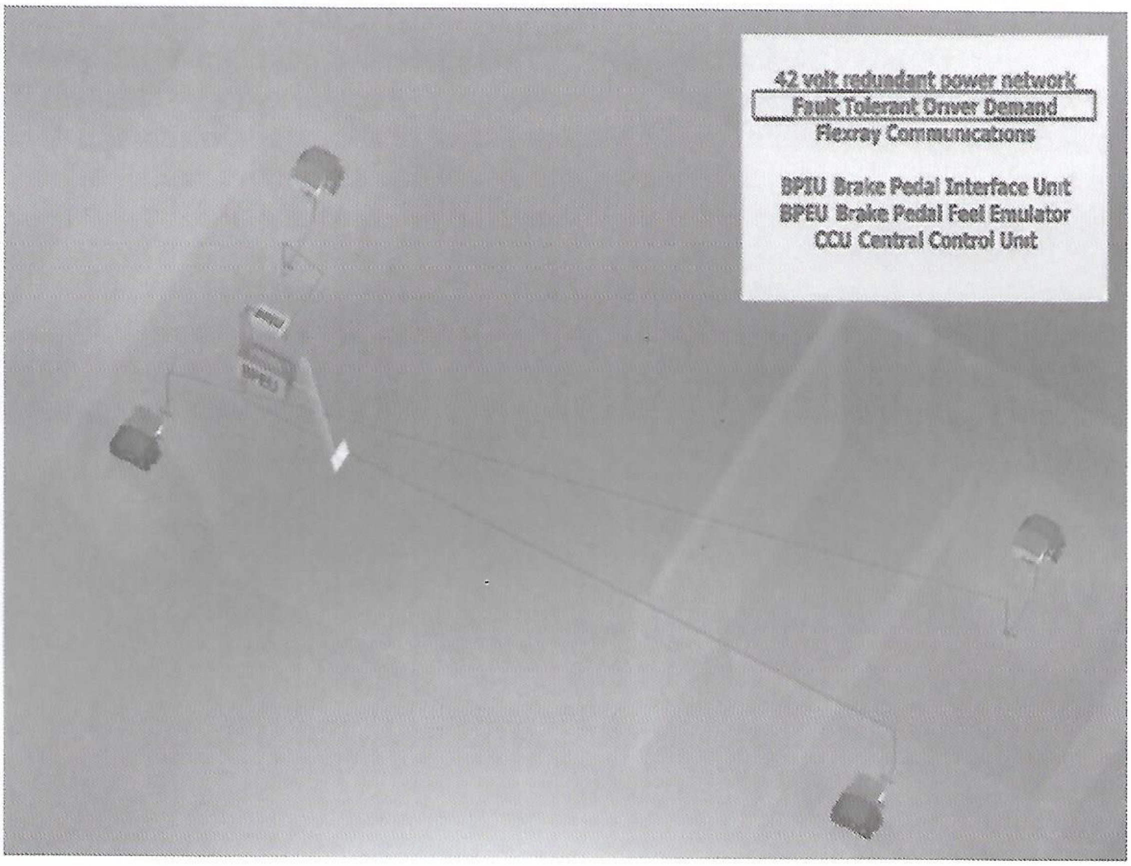


PBR Electro-Mechanical Brake Callipers


42 volt redundant power network
Fault Tolerant Driver Demand
Flexray Communications
BPIU Brake Pedal Interface Unit
BPEU Brake Pedal Feel Emulator
CCU Central Control Unit
42v
42v

The Sequel's 42 Volts electrical systems are independent of each other to provide back up

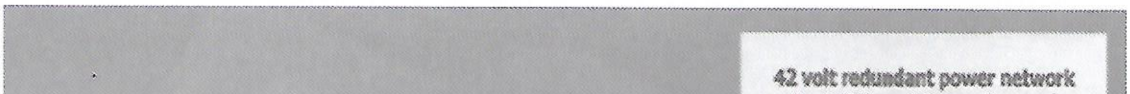
PBR ELECTRO-MECHANICAL BBW continued...



42 volt redundant power network
Fault Tolerant Driver Demand
Flexray Communications

BPIU Brake Pedal Interface Unit
BPEU Brake Pedal Feel Emulator
CCU Central Control Unit

The Brake Pedal Emulator consists of multiple redundancies



42 volt redundant power network
Fault Tolerant Driver Demand
Flexray Communications

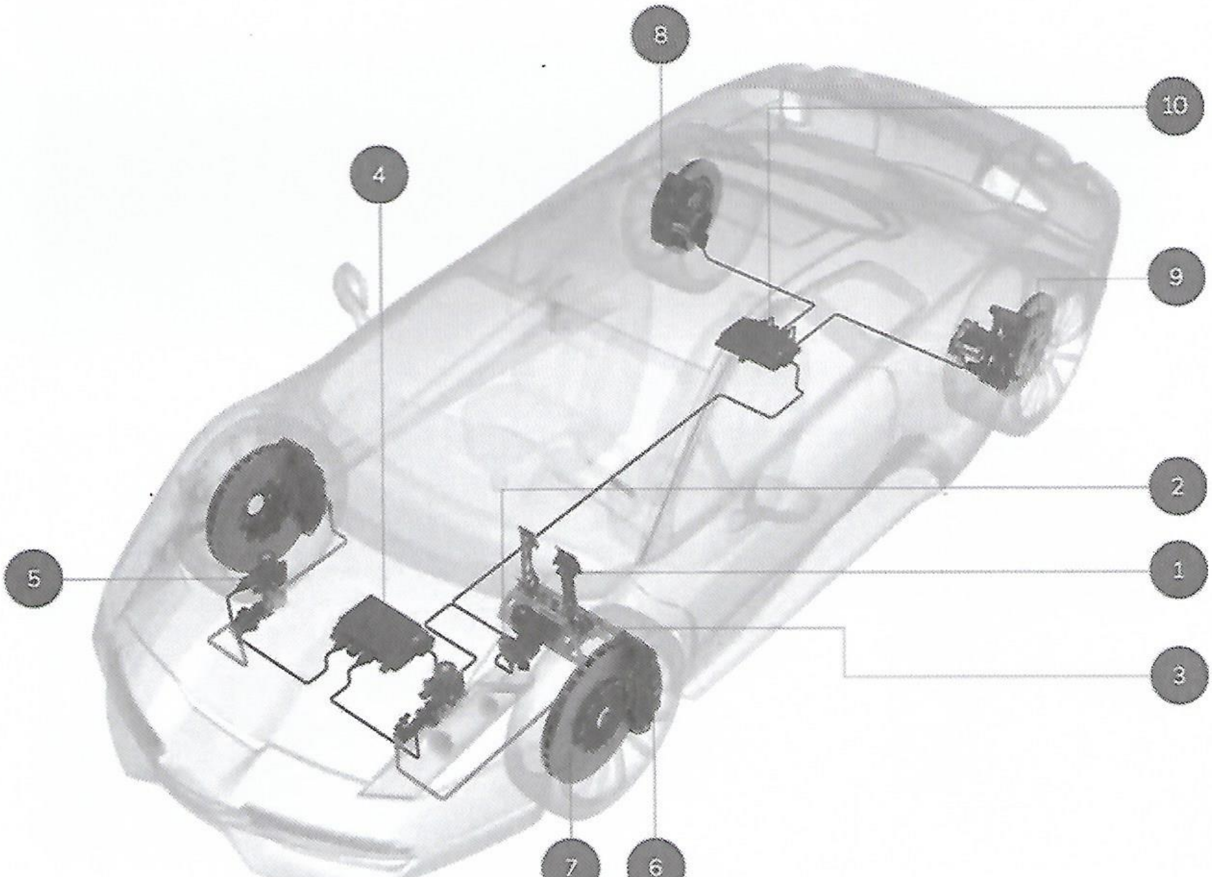
BPIU Brake Pedal Interface Unit
BPEU Brake Pedal Feel Emulator
CCU Central Control Unit

Communication is via a Flexray data network

BREMBO ON-ROAD BBW PROTOTYPE

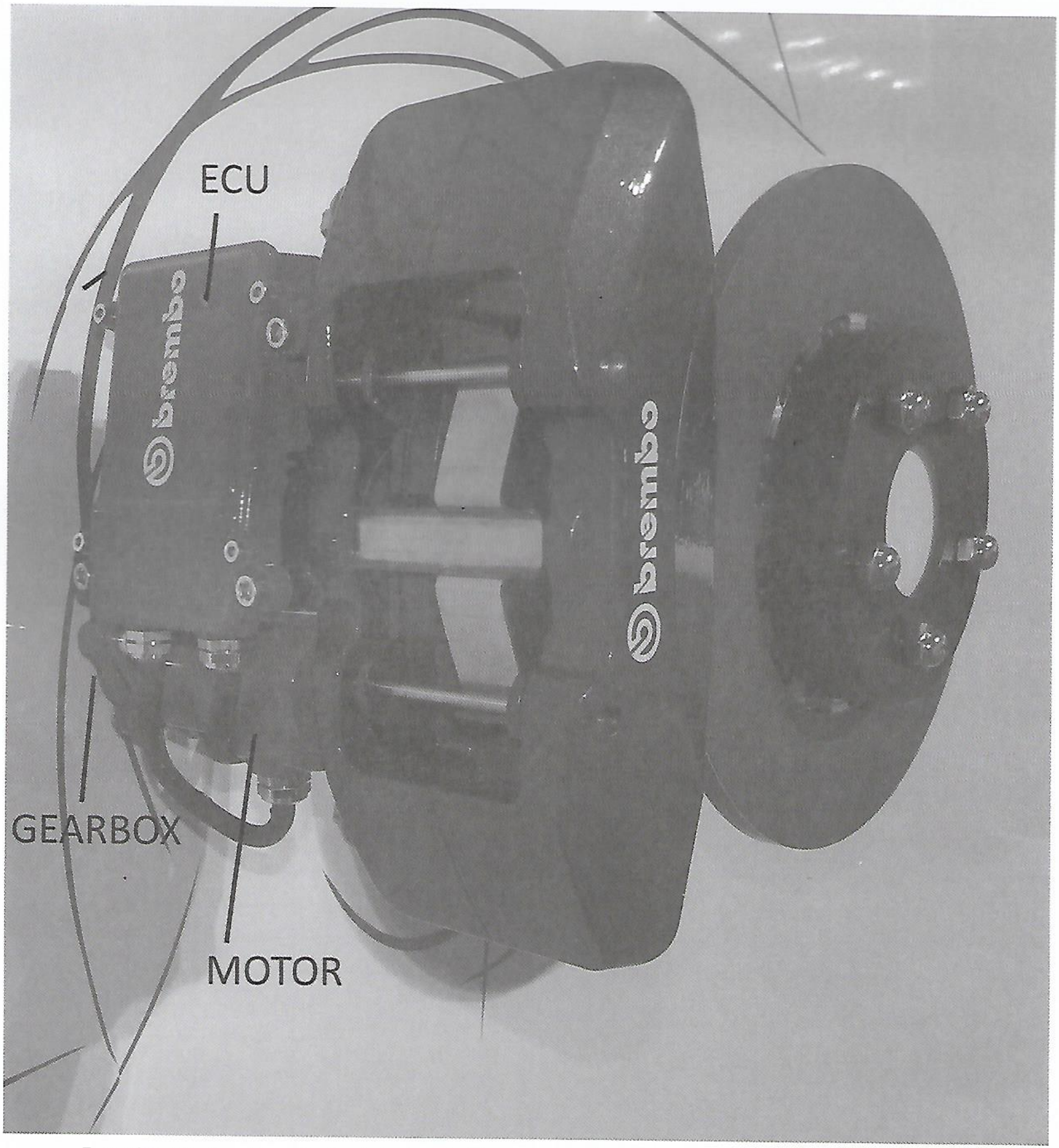
In 2017 Brembo released information about a systems designed for road registered cars. Brembo is heavily involved in F1 racing brakes and it has transferred what it knows for road use. The premise of their system is that the hydraulic system is narrowed down to two Electro-Hydraulic Actuators, one located adjacent to each of the front wheels. The rest of the system is electronic. Brembo claims that the reaction time is around 100ms (1/3 to 1/5 the time of traditional brake systems).

Redundancies are back-up functionality. All current road registered vehicles have a hydraulic back-up which is linked to the front brakes. Brembo's prototype uses only electrical redundancies in the form of multiple position sensors, hard wiring to provide back-up to the data bus network and a dedicated back-up electrical supply (battery).



Brembo on-road BBW system			
1	Brake Pedal	2	Pedal Stroke Simulator
3	Pedal Stroke Sensor	4	Front Brake ECU
5	Front Brake Electro-Hydraulic Actuator (1 of 2)	6	Front Hydraulic Brake Calliper
7	Front Brake Disc Rotor	8	Rear Electro-Mechanical Brake Calliper
9	Rear Brake Disc Rotor	10	Rear Brake ECU

BREMBO ON-ROAD BBW PROTOTYPE continued...


ECU
brembo
brembo
GEARBOX
MOTOR

Brembo Electro-Meachnical Brake Callipers on a display board at a Motor Expo in 2017